# FAST LOAD FLOW TECHNIQUES OF LARGE SCALE SYSTEMS

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*By*
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# CERTIFICATE

Certified that this work 'FAST LOAD FLOW TECHNIQUES OF LARGE SCALE SYSTEMS' by Shri Pankaj Gupta has been carried out under my supervision and has not been submitted elsewhere for a degree.

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## ABSTRACT

Exhaustive studies have been conducted in the field of load flow analysis. The results of these studies have pointed out the advantages of the fast converging methods like Newton-Raphson especially in polar coordinates and Fast Decoupled method . The former method has the disadvantage of large memory requirement and greater computation time. These methods (in particular Newton-Raphson) become a practical tool only when sparsity of the coefficient matrix and bus admittance matrix are exploited. The use of ordered elimination reduces the computation time further.

In this thesis, programs have been developed to perform LF studies by all the three methods such as, NR , D.C. and FD. Sparsity ordered eliminations are the key features of the program. A comparative study of these three methods with reference to computation time and memory requirements is also given.

# CHAPTER 1

# INTRODUCTION

The modern trend is to form a grid system of all the available energy sources i.e. towards interconnecting all types of generating stations. This provides the greatest advantage of meeting the load supply demands economically at all times. The power supply undertakings must keep pace with the load growth. In addition to the above, care must be taken so as not to overload the interconnecting systems resulting into their instability.

Load flow analysis is very important when new components or additions to existing ones are considered. With proper and accurate load flow studies, the interruption of power can be minimised. Load flow calculations are necessary at the initial stage for the purpose of planning, operation and control. It provides voltage magnitude and phase angle at each bus and power flows including line losses in each element of the power system network. Apart from determining the steady state operating conditions of a power system network for the purpose of planning, operation and control, load flow calculations also provide initial conditions for transient stability studies.

Prior to the advent of digital computer, load flow studies were performed on A.C. calculating boards i.e. network

analysers. A calculating board is a single phase scaled down model of a balanced three phase system. The board being made up of a number of elements viz. resistances, inductances and capacitances, all of which are adjustable, along with a number of sources and measuring instruments. Initial adjustments in this case usually take a lot of time since each adjustment at any bus affects values of pertinent quantities at other buses. In addition to this, considerable amount of time is lost in recording observations.

The appearance of the digital computers revolutionized the whole concept of load flow calculations. Mathematical model (i.e. equations) which were once thought to be cumbersome and of purely theoretical interest became practically feasible. The ease with which computers can handle arithmetic operations gave a boost to the numerical methods. The mathematical model for the purpose of load flow studies is a set of non-linear algebraic equations. The non linearity of the system of equations defies an exact analytical solution and one must resort to some iterative techniques which will render a sufficiently accurate numerical solution. There is no dearth of numerical techniques available, only the enormous computational effort is a deterrent, but with the coming of the digital computer, it is no longer a stumbling block, for now the problem is to develop an algorithm for solving these equations on the computer.

The first practical methods to solve these power system network equations on a digital computer, appeared in literature in 1956 [1,2]. These methods (one of the methods was the gauss-seidel technique) required minimum storage and hence were well suited to the first generation computers. However these methods were slow in convergence and thus not very well suited to handle large systems. Any method which has to handle a large system must possess the following two key features.

1. Nominal storage requirements
2. Reliable and fast in convergence.

The Newton-Raphson method's quadratic convergence property was highlighted around the same time [3,4] but was found to be computationally uncompetitive. The application of sparsity programmed ordered elimination by Tinmy and Walker to the Newton-Raphson method reduced the storage requirement and also optimized the computation time to such an extent that Newton-Raphson method gained popularity over and above other methods [5], and has now come to be widely regarded as the general purpose load flow approach [6]. The decoupled and fast decoupled load flow techniques are modifications of the Newton-Raphson method which exploit the loose physical interaction between MW and MVAR flows in a power system. Storage and computation time are further minimized in the above mentioned methods, without appreciable loss in accuracy.

Present day power systems are large and complex because of greater interconnection. To analyse such a large scale system on a digital computer with limited memory application of sparsity oriented ordered elimination techniques are needed.

Keeping the above factors in view, programs are developed for the three methods viz. Newton-Raphson, Decoupled and Fast Decoupled. These programs have been tested for a 100 bus 128 line system of UPSEB. Programs are capable of handling a larger system; data storage requirements of the large system are the limiting factors which dictate system size that can be simulated on a particular digital computer. Although the use of magnetic tapes can overcome this problem to some extent, one has to pay in terms of speed. The main features of the programs developed in this thesis are:

1. User oriented input/output format
2. Storage of only non-zero elements of $Y_{bus}$
3. Storage of only non-zero elements of Jacobian
4. Ordered elimination of the Jacobian equation

The chapter-wise summary of the work covered in this thesis is given as follows.

Chapter 2 is devoted to the theoretical aspects of the methods used viz. Newton-Raphson, Decoupled and the Fast Decoupled method. A brief account of each method and their relative merits are also discussed in this chapter.

Chapter 3 deals with sparsity ordered elimination. A general description of the technique and in specific, its application to power system problem has been given.

Chapter 4 deals with the case study of the following systems

14 bus 20 lines IEEE system

57 bus 80 lines IEEE system

and 100 bus 128 lines UPSEB system.

The advantage of sparsity ordered elimination are elaborated by comparasion of results for the three systems in relation to memory requirements and computer time. Detailed flow chart for all the methods used as well as results etc. are given.

Chapter 5 concludes with the specific findings in this thesis along with future scope of the work.

# CHAPTER 2

# LOAD FLOW TECHNIQUES

## 2.1 INTRODUCTION:

This chapter deals with the currently favoured methods for load flow studies. A literature survey will reveal a host of algorithms which have been suggested from time to time to solve this problem of load flow analysis. An excellent review of the major portion of work done in this field has been given in [7]. In general it is difficult to point out the best method for a particular application. The relative properties and performances of different load flow methods can be influenced substantially by the types and size of the problems to be handled and also by the computing facilities available. Any final choise is invariably a compromise between the various criteria of goodness by which the load flow methods are to be compared with each other. Every such criteria is directly or indirectly associated with financial cost. This chapter spells out the details of the load flow problem and the numerical techniques for its solution.

## 2.2 LOAD FLOW STUDIES:

The objective of the load flow study is to determine the phase angle and reactive power on each P-V bus and the phase angle and voltage magnitude at each P-Q bus subject to the constraints on the real and reactive power at

P-Q buses and the real power and voltage magnitude at the P-V buses. Based upon this it is possible to classify the buses into three categories.

## 2.3 BUS CATEGORIZATION:

The buses are categorized depending on the quantity specified at the bus

a) Load or a P-Q bus

b) Voltage controlled or a P-V bus

c) Slack or swing bus

a) Load or a P-Q bus: For this type of a bus, we know a priori $P_{L_i}$ and $Q_{L_i}$ and specify $P_{G_i}$ and $Q_{G_i}$. In effect we thus specify the bus injections $P_i$ and $Q_i$. Solution of the load flow equations will render $|V_i|$ and $\theta_i$. A load bus which due to its lack of generating equipment, is characterized by zero $P_{G_i}$ and $Q_{G_i}$ evidently falls in this category.

b) P-V or a voltage controlled bus: For this type of a bus we know a priori $P_{L_i}$ and $Q_{L_i}$ and specify $|V_i|$ and $P_{G_i}$. In effect, we thus specify the bus powers $P_i$. Solution of the load flow equations render $Q_i$ (and hence $Q_{G_i}$) and $\theta_i$. This is called a voltage controlled bus because its voltage can be controlled.

c) Slack or swing bus: This is the reference bus where the voltage magnitude and phase angle are specified. One of the generator with the maximum real power capabilities must be

selected as the swing bus to provide for the additional real and reactive power to supply line losses because these are unknown till the final load flow solution is obtained. The variables of interest at this bus are the real and reactive power.

Assuming balanced 3-phase conditions, which is usually done for the purpose of load flow studies, the transmission system can be represented by its positive sequence network. The nodal admittance matrix can be expressed as follows

$$\underset{(n\times 1)}{I_{BUS}} = \underset{(n\times n)}{Y_{BUS}} \quad \underset{(n\times 1)}{V_{BUS}} \tag{2.1}$$

The above equation can be written in the following form for a $P^{th}$ node.

$$I_p = \sum_{q=1}^{n} Y_{pq} V_q \tag{2.2}$$

$$p = 1, 2, \ldots, n$$

This equation simply states that the currents at any node or bus is the algebraic sum of all the currents entering or leaving the node. The power at any bus is calculated by the $V_p I_p^*$ product.

$$V_p I_p^* = V_p \sum_{q=1}^{n} Y_{pq}^* V_q^* \tag{2.3}$$

separating equation (2.3) into the real and imaginary parts gives us the expressions for real and reactive powers i.e.

$$P_p = \text{REAL}\ [V_p \sum_{q=1}^{n} Y^*_{pq}\ V^*_q\ ] \qquad (2.4)$$

$$Q_p = \text{IMAG}\ [V_p \sum_{q=1}^{n} Y^*_{pq}\ V^*_q\ ] \qquad (2.5)$$

$$p = 1,2,\ldots n.$$

With the following substitutions for $Y_{pq}$, $V_p$ and $V_q$

$$Y_{pq} = G_{pq} + jB_{pq}$$

$$V_p = |V_p|\ (\cos \Theta_p + j \text{ sine } \Theta_p\ )$$

$$V_q = |V_q|\ (\cos \Theta_q + j \text{ sine } \Theta_q\ )$$

equations (2.4) and (2.5) become

$$P_p = |V_p| \sum_{q=1}^{n} ((G_{pq} \cos \Theta_{pq} + B_{pq} \text{ sine } \Theta_{pq})|V_q|) \qquad (2.6)$$

$$Q_p = |V_p| \sum_{q=1}^{n} ((G_{pq} \text{ sine } \Theta_{pq} - B_{pq} \cos \Theta_{pq})|V_q|) \qquad (2.7)$$

Let us examine the number of knowns and unknowns at the three type of buses.

| | | |
|---|---|---|
| suppose total number of buses | = | N |
| slack bus | = | 1 |
| Number of P-Q buses | = | M |
| Number of P-V buses | = | N-M-1 |

If V and $\theta$ are knownat all the buses we can find out P and Q at all buses using equations (2.6) and (2.7) i.e. V and $\theta$ are the state variables.

Total number of possible unknowns = 2N

As voltages at all P-V buses are known and also at slack bus V is assumed 1.0 p.u. and angle $\theta_s = 0^o$.

$$\begin{aligned}\text{Number of knowns} &= N-M-1+2 \\ &= N-M+1 \\ \text{Number of unknowns} &= 2N-(N-M+1) \\ &= N+M-1\end{aligned}$$

Hence (N+M-1) equations are needed to solve for the unknowns. For each load bus P and Q are known so we can write two equations at each P-Q bus. Also P is known at each P-V bus so one equation for P can be written for each P-V bus.

$$\begin{aligned}\text{Number of equations for (N-M-1) P-V buses} &= N-M-1 \\ \text{Number of equations for M P-Q buses} &= 2M \\ \text{Total number of equations} &= 2M+N-M-1 \\ &= N+M-1\end{aligned}$$

Thus the number of equations is equal to the number of unknowns [Note this has been possible, only if $\theta_{pq}$ i.e. $(\theta_p - \theta_q)$ is treated as one unknown by taking one of the buses as reference].

Bus constraint equations are

$$\Delta P_p = P_p^{sp} - P_p^{cal} \tag{2.9}$$

$$\Delta Q_p = Q_p^{sp} - Q_p^{cal} \tag{2.10}$$

where superscript 'sp' and 'cal' stand for specified and calculated respectively. $P_p^{cal}$ and $Q_p^{cal}$ are obtained from the equations (2.6) and (2.7). As can be seen by the appearence of cos $\theta_{pq}$ and sine $\theta_{pq}$ terms in the expressions for $P_p^{cal}$ and $Q_p^{cal}$, it is a system of non-linear equations and one has to resort to numerical techniques to obtain a solution. The solution of these equations for V's and $\theta$'s is the load flow problem.

## 2.4 NEWTON RAPHSON METHOD:

When there is no mismatch between the specified and calculated powers equations (2.9) and (2.10) [in matrix notation] become

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = 0 \tag{2.11}$$

Applying Newton-Raphson method we have

$$
\begin{bmatrix} \Delta P_1 \\ \Delta P_2 \\ \Delta P_3 \\ \vdots \\ \Delta P_{N-1} \\ \hline \Delta Q_1 \\ \Delta Q_2 \\ \vdots \\ \Delta Q_M \end{bmatrix}
=
\left[\begin{array}{cccc:cccc}
\frac{\partial \Delta P_1}{\partial \theta_1} & \frac{\partial \Delta P_1}{\partial \theta_2} & \cdots & \frac{\partial \Delta P_1}{\partial \theta_{N-1}} & \frac{\partial \Delta P_1}{\partial V_1}|V_1| & \frac{\partial \Delta P_1}{\partial V_2}|V_2| & \cdots & \frac{\partial \Delta P_1}{\partial V_M}|V_M| \\
\frac{\partial \Delta P_2}{\partial \theta_1} & \frac{\partial \Delta P_2}{\partial \theta_2} & \cdots & \frac{\partial \Delta P_2}{\partial \theta_{N-1}} & \frac{\partial \Delta P_2}{\partial V_1}|V_1| & \frac{\partial \Delta P_2}{\partial V_2}|V_2| & \cdots & \frac{\partial \Delta P_2}{\partial V_M}|V_M| \\
\cdots & & \cdots & & \cdots & & \cdots & \\
\cdots & & \cdots & & \cdots & & \cdots & \\
\frac{\partial \Delta P_{N-1}}{\partial \theta_1} & \frac{\partial \Delta P_{N-1}}{\partial \theta_2} & \cdots & \frac{\partial \Delta P_{N-1}}{\partial \theta_{N-1}} & \frac{\partial \Delta P_{N-1}}{\partial V_1}|V_1| & \frac{\partial \Delta P_{N-1}}{\partial V_2}|V_2| & \cdots & \frac{\partial \Delta P_{N-1}}{\partial V_M}|V_M| \\
\hdashline
\frac{\partial \Delta Q_1}{\partial \theta_1} & \frac{\partial \Delta Q_1}{\partial \theta_2} & \cdots & \frac{\partial \Delta Q_1}{\partial \theta_{N-1}} & \frac{\partial \Delta Q_1}{\partial V_1}|V_1| & \frac{\partial \Delta Q_1}{\partial V_2}|V_2| & \cdots & \frac{\partial \Delta Q_1}{\partial V_M}|V_M| \\
\frac{\partial \Delta Q_2}{\partial \theta_1} & \frac{\partial \Delta Q_2}{\partial \theta_2} & \cdots & \frac{\partial \Delta Q_2}{\partial \theta_{N-1}} & \frac{\partial \Delta Q_2}{\partial V_1}|V_1| & \frac{\partial \Delta Q_2}{\partial V_2}|V_2| & \cdots & \frac{\partial \Delta Q_2}{\partial V_M}|V_M| \\
\cdots & & \cdots & & & \cdots & \cdots & \\
\cdots & & \cdots & & & \cdots & \cdots & \\
\frac{\partial \Delta Q_M}{\partial \theta_1} & \frac{\partial \Delta Q_M}{\partial \theta_2} & \cdots & \frac{\partial \Delta Q_M}{\partial \theta_{N-1}} & \frac{\partial \Delta Q_M}{\partial V_1}|V_1| & \frac{\partial \Delta Q_M}{\partial V_2}|V_2| & \cdots & \frac{\partial \Delta Q_M}{\partial V_M}|V_M|
\end{array}\right]
\begin{bmatrix} \Delta \theta_1 \\ \Delta \theta_2 \\ \Delta \theta_3 \\ \vdots \\ \Delta \theta_{N-1} \\ \hdashline \frac{\Delta V_1}{|V_1|} \\ \frac{\Delta V_2}{|V_2|} \\ \vdots \\ \frac{\Delta V_M}{|V_M|} \end{bmatrix}
\tag{2.12}
$$

In short the above can be written in the form

$$\begin{bmatrix} \Delta P \\ \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & N \\ \\ M & L \end{bmatrix} \begin{bmatrix} \Delta \theta \\ \\ \frac{\Delta V}{|V|} \end{bmatrix} \qquad (2.13)$$

where

$$\begin{bmatrix} H & N \\ M & L \end{bmatrix}$$ is called the Jacobian matrix

H — Partial derivatives of P w.r.t. θ's

L — Partial derivatives of Q w.r.t. V's

N — Partial derivatives of P w.r.t. V's

M — Partial derivatives of Q w.r.t. θ's

The $\Delta V$'s are divided by $|V|$ and corresponding elements of Jacobian are multiplied by 'V' to bring about a symmetry in the elements of the Jacobian.

It can be shown that

for $p \neq q$

$$H_{pq} = L_{pq} = |V_p| \; |V_q| \; (G_{pq} \text{ sine } \theta_{pq} - B_{pq} \cos \theta_{pq}) \qquad (2.14)$$

$$N_{pq} = -M_{pq} = |V_p| \; |V_q| \; (G_{pq} \cos \theta_{pq} + B_{pq} \text{ sine } \theta_{pq}) \qquad (2.15)$$

For p = q we have

$$H_{pp} = -Q_p - B_{pp} \; |V_p|^2 \qquad (2.16)$$

$$L_{pp} = Q_p - B_{pp} \; |V_p|^2 \qquad (2.17)$$

$$N_{pp} = P_p + G_{pp} |V_p|^2 \tag{2.18}$$

$$M_{pp} = P_p - G_{pp} |V_p|^2 \tag{2.19}$$

Where $P_p$ and $Q_p$ are calculated from equations (2.6) and (2.7).

The solution of equation (2.13) gives us the $\Delta\theta$'s and $\Delta$ V's which are used to update earlier estimates of $\theta$'s and V's and the process is repeated till the mismatch $\Delta$ P and $\Delta$ Q become less than a pre-assigned tolerance value $\epsilon$. When this is achieved, the iterative process is stopped as the desired accuracy has been obtained.

## 2.5 STEPS FOR THE NEWTON-RAPHSON ITERATIVE SCHEME:

1. If nothing is available regarding the actual value of variables at the buses assume a flat start, assign V at all buses equal to slack bus voltage and angles equal to slack bus angle i.e. zero. Set iteration count 'K' to one.

2. Calculate $P^{cal}$ and $Q^{cal}$ (using equation (2.6) and (2.7)) with values of V's and $\theta$'s as in step (1).

3. Calculate power mismatch at all buses using equation (2.9) and (2.10).

4. Test for convergence by checking power mismatch. If $\Delta$P's and $\Delta$Q's at all buses are less than a pre-defined value $\epsilon$ ,we jump out of the iterative loop and go to step (10).

5. Check if the number of iterations has exceeded the predefined value 'ITMAX' (say), if it has exceeded go to step (12).

6. Calculate the elements of the Jacobian using equations (2.14) through (2.19).

7. Solve equation (2.13) for $\Delta\,\theta$'s and $\frac{\Delta V}{|V|}$'s using one of the direct methods of solution (e.g. Gaussian elimination)

8. Update the voltages and angles at all the buses using the correction factors obtained in step (7). Increment iteration count by '1'

$$|V|^{K+1} = |V|^{K} + \left|\frac{\Delta V}{V}\right|^{K} |V| \tag{2.20}$$

$$\theta^{K+1} = \theta^{K} + \Delta\,\theta^{K} \tag{2.21}$$

9. With the voltages and angles as given equations (2.20) and (2.21) start the $(K+1)^{th}$ iteration i.e. go to step (2).

10. Using the latest voltage and estimates, calculate slack bus power, line flows and line losses.

11. Go to Step 13 .

12. Convergence not obtained in 'K' iterations.

13. Convergence obtained in 'K' iterations. Print bus status, line flows, line losses.

The main disadvantage of this method is that the storage requirements and computation work involved is enormous. For a 'N' bus system with 'M' P-Q buses the order of Jacobian is (N+M-1). Thus for a typical 100 bus problem with 19 P-V buses including slack bus, which has been carried out in this thesis, we require 32.4 K of computer memory for storing the Jacobian matrix. Storage of data, bus admittance matrix etc. are over and above this. Bus admittance matrix for a 100 bus system will contribute towards a storage requirement of 10K. Thus Jacobian and bus admittance matrix together take the major portion of total storage requirements for any problem. With full storage schemes the solution is limited to small problems because of memory restrictions. The Newton-Raphson method together with sparsity and ordered elimination technique [5] is a powerful tool for obtaining load flow solution, as it optimizes memory requirement as well as computation time. The number of iterations required for solution is virtually independent of problem size. This is strictly true for programs without additional features like automatic tap adjustment of a transformer, Q limit checks etc. which may require additional iterations. A program adjusted for Q limits may take an additional two or more iterations.

## 2.6 DECOUPLED METHOD:

In all the decoupled methods the load flow equations have been derived from the Newton-Raphson formulation in polar coordinates to reduce memory requirement and computational

efforts. These methods are based on neglecting the coupling terms M and N of the Jacobian matrix in the Newton-Raphson method, on the assumption that the coupling between real bus power versus bus voltage magnitude and reactive power versus bus voltage angle is relatively weak. Any such approximations to the Jacobian inevitably sacrifices the true quadratic convergence property, but compensating computational benefits can accrue. Based upon these assumptions equation (2.13) reduces to two sets of independent equations for P's and Q's.

$$[\Delta P] = H\,[\Delta Q] \tag{2.22}$$

$$[\Delta Q] = L\,\left[\frac{\Delta V}{|V|}\right] \tag{2.23}$$

Equations (2.22) and (2.23) are formulated and solved successively. The latest values of $\theta$ are used to solve for V. The decoupled method converges as reliably as the formal Newton-Raphson Method, although it takes more number of iterations to achieve accuracies compatable to the Newton's method. This however is not necessary as convergence to practical accuracies takes more or less the same number of iterations. The saving in terms of memory requirements is nearly 75% for Jacobian element storage although overall saving of the memory is only of the order of 40-50%. The computation time per iteration is also 10-20% less than Newton-Raphson Method.

## 2.7 FAST DECOUPLED METHOD:

The decoupled method can be further simplified without appreciable loss of accuracy [7,8]. In practical power system the following assumptions hold good.

1. $\theta_{pq}$ is small .
2. $G_{pq}$ sine $\theta_{pq} << B_{pq}$.
3. $Q_p << B_{pp} |V|^2$ .

Applying these assumptions to equations (2.22) and (2.23) [reproduced below].

$$[\Delta P] = H [\Delta\theta]$$

$$[\Delta Q] = L [\frac{\Delta V}{|V|}]$$

We have

$$[\Delta P] = [V B'V] ][\Delta\theta] \tag{2.24}$$

$$[\Delta Q] = [V B''V] [\frac{\Delta V}{|V|}] \tag{2.25}$$

The elements of the matrix B' and B'' are strictly elements of [-B]. The decoupling process is given a final shape by.

(a) Omitting from [B'] the representation of those network elements that predominantly affect MVAR flows i.e. shunt reactances and off nominal in phase taps.

(b) Omitting from [B''] the angle shifting effects of phase elements.

(c) While calculating for $P^{th}$ bus taking the left hand 'V' terms (for $P^{th}$ bus) in equations (2.24) and (2.25) on to the left hand side of the equations and then in equation (2.24) removing the influence of MVAR flows on the calculations of $\Delta\theta$ by setting all right hand 'V' terms to 1 p.u.

With these assumptions the relevant equations for Fast-Decoupled load flow are

$$\left[\frac{\Delta P}{|V|}\right] = [B'] \, [\Delta \theta] \tag{2.26}$$

$$\left[\frac{\Delta Q}{|V|}\right] = [B''] \, [\Delta V] \tag{2.27}$$

This method though not possessing the true quadratic convergence of the Newton-Raphson method, converges very fast as the time per iteration is very less. It is as reliable as the Newton-Raphson method within the acceptable limits of accuracy. Adjusted solutions, to incorporate all other additional features, in this case, will take more number of iterations but since time per iteration is very less compared to Newton-Raphson method the overall computation time is not affected significantly.

In this chapter we have outlined the various methods of current interest. The methods in themselves are not new but form a powerful tool when sparsity of the Jacobian matrix is exploited. Implemented as such, they may not be able to handle systems of 500 bus or more (especially Newton-Raphson method) whereas using sparsity, we can handle system sizes of 1000 buses and above with little difficulty.

# CHAPTER 3

## SPARSITY AND OPTIMAL ORDERING

### 3.1 INTRODUCTION:

The sparsity occurs in some form in most of the physical systems such as communication network, current theory, family trees, organization structure and sociograms. Let a physical system be described by a set of 'n' algebraic linear equations of the form

$$[A]\ x = y \tag{3.1}$$

The problem is to determine the solution vector x by Gaussian elimination method such that the computational efforts and hence, the time of computation i.e. the cost is minimized. Following Von Neuman, the number of multiplication required to obtain solution is counted as a measure of computing time. Therefore if only the number of multiplication is to be counted, a reduced matrix 'M' of the coefficient matrix A [Eqn. 3.1 ]. whose elements are defined as

$$\begin{aligned} m_{ij} &= 1 \quad \text{if } m_{ij} \neq 0 \\ &= 0 \quad \text{if } m_{ij} = 0 \end{aligned} \tag{3.2}$$

contains all the required information for solving the problem.

Let the number of multiplication to process the $i^{th}$ row be $m_i$ and therefore, for the entire system, the total number of multiplication

$$\emptyset = \sum_{i=1}^{n} m_i \qquad (3.3)$$

where n is the number of equations i.e. order of the system.

## 3.2 FUNCTIONAL EQUATIONS:

Optimal elimination is actually a topological problem which can be formulated using notation from graph theory. Some systems such as electrical networks may be thought of being their own graph, thus a picture of one of these systems with slight modification could serve as its own graph inspite of the fact that there may be more than one scaler quantity associated with each node, other systems such as those arise from difference equations may have no direct graph. For these systems, the following procedure is adopted to construct its graph. With each equation in the coefficient matrix 'A' (eqn. 3.1), there is associated a node in the system graph and with each non-zero term,

$$a_{ij} \quad \text{for } i = 1, \ldots n \qquad (3.4)$$
$$j = 1, \ldots n$$

there is associated an undirected branch between the ith and the jth node.

The system graph will be referred to as 'G'; during the elimination process it is modified, just as the rows of the coefficient matrix 'A' are modified. Let $G^i$ is a graph obtained by eliminating the ith node from system graph G

[i.e. processing ith row of the corresponding coefficient matrix 'A']. Let W(G) be defined to be the number of multiplication required to solve optimally the system [i.e. [A]x = y] whose graph is 'G' and let $\mathcal{}$(i) be one plus the degree of $i^{th}$ node in the graph 'G'. From this, it is clear, that, W(G) is a minimum value of $\emptyset$ and $e_i$ is the number of multiplications required to eliminate ith row from the given system whose graph is G. Then,

$$W(G) = \text{Min}\ \emptyset\ [\epsilon_i] \tag{3.5}$$

$$W(G) = \text{Min}\ [e_i + W(G^i)] \tag{3.6}$$

where $\epsilon_i$ is the permutation of ordering.

Bellman uses the term 'policy' to describe a specific permutation i.e. a certain policy results in a permutation for which it is then possible to evaluate the number of multiplications or work. The optimal policy corresponds to the minimum work.

Following Bellman, it is possible to choose any initial policy i.e. method of ordering the nodes i.e. equations or rows of corresponding coefficient matrix and proceed iteratively to obtain the solution of the above equations i.e. eqn. (3.6) whose solution is unique even though the optimal policy may not be unique.

Let $W_o[G]$ be the number of multiplications needed using initial policy. Then we have from the equation (3.6)

$$W_N[G] = \min_i \; [e_i + W_{N-1}[G^i]] \qquad (3.7)$$

$$N = 1, \ldots n$$

Here $W_N[G]$ is the number of multiplications required to solve optimally the system having 'n' equations i.e. whose coefficient matrix has 'n' rows and G is the corresponding graph. The solution of these equation which is dynamic programming will yield the following result. At each step in the elimination scheme, eliminate that node next which has the smallest degree.

Such problems can easily be formulated and solved by the principle of dynamic programming which is developed by Richard Bellman because these problems belong to a category known as the multistage decision process, typical example being that of travelling sales man problem. Here we take the initial decision which is arbitrary and based upon this decision all other decisions are optimal, say in this particular case, the initial decision is that the ith row of the coefficient matrix 'A' is processed first i.e., ith node of the corresponding graph 'G' is eliminated first; because of taking this decision, the cost involved $e_i$ where $e_i$ indicates the number of multiplications needed to process

the $i^{th}$ row of coefficient matrix A, will be the measure of the cost to process the ith row. Because of taking this decision, the graph 'G' will change to $G^i$ and number of nodes will become (N-1) and hence the formulation using dynamic programming will yield the result,

$$W_N(G) = \min_i \; (e_i + W_{N-1}(G^i)) \qquad N = 1 \dots n \tag{3.8}$$

The main advantage of using this formulation is; at any stage we deal with only one variable i.e. instead of solving all the n variables together, they are solved one at a time, however n number of times.

## 3.3 DIRECT SOLUTION OF SPARSE NETWORK EQUATIONS BY OPTIMALLY ORDERED ELIMINATION:

For the sparse systems, which normally occur in power system network formulation, solution is obtained by optimally ordered elimination. This method consists of two parts [9,10,11].

1) A scheme of recording the operation of triangular decomposition of a matrix such that repeated direct solution can be obtained without repeating the triangularization process.

2) A scheme of ordering the operation such that it tends to conserve sparsity of the original system.

The first part of the method is applicable to any matrix. However the application of the second part i.e. ordering to conserve sparsity is limited to sparse matrix in which the pattern of non-zero elements is symmetric and for which an arbitrary order of decomposition does not affect adversely the numerical accuracy, such matrices are normally characterized by a strong diagonal. The coefficient matrix in the case of the load flow problem belong to this category where more than 90% elements are zero at off diagonal locations. Let us take the equation

[A] x = y which can be expanded as

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ \cdot \\ \cdot \\ \cdot \\ Y_n \end{bmatrix} \quad (3.9)$$

The matrix 'A' is changed to augumented matrix A by adding in (n+1)th column, the known constants of column vector Y. By factored LU decomposition of the coefficient matrix, we obtain the following matrix known as the table of factors.

$$\begin{bmatrix} d_{11} & u_{12} & \cdots & u_{1n} & u_{1n+1} \\ \ell_{21} & d_{22} & \cdots & u_{2n} & u_{2n+1} \\ \vdots & \vdots & & \vdots & \vdots \\ \ell_{n1} & \ell_{n2} & \cdots & d_{nn} & u_{nn+1} \end{bmatrix} \tag{3.10}$$

where the elements of the matrix are defined below

$$d_{ii} = \frac{1}{a_{ii}^{(i-1)}}$$

$$u_{ij} = a_{ij}^{(i)}$$

$$L_{ij} = a_{ij}^{(j-1)}$$

When the matrix to be decomposed is sparse the order in which the rows are processed affect the number of non-zero terms in the upper triangular matrix. If a programming scheme is such that it processes and stores,only the non-zero terms, a great swing in operation and memory can be achieved by keeping the table of factors as sparse as possible. The absolute optimal ordering scheme would result in the least terms in the table of factors.

However the absolute scheme of ordering has not been developed as yet, we give below the following effective scheme of near optimal ordering.

1. In this scheme the coefficient matrix of a physical system is ordered before hand. Here the rows with only one non-zero element at the off diagonal locations is numbered first-row with two non-zero elements is numbered two and so on. Finally the row with the maximum non-zero elements is numbered last. The rows of coefficient matrix A in the process of elimination, are processed in this sequence. From the graph point of view, a node with a degree one is numbered one, a node with a degree two is numbered two and finally the row with the highest degree is numbered last. This algorithm is simple to program and fast to execute , however the main disadvantage of the algorithm is that it does not take into account the changes in the pattern of non-zero elements in the coefficient matrix.

2. This algorithm has been derived by using the technique of dynamic programming by R. Bellman, In this algorithm, in the process of elimination, we eliminate that row next which has the minimum number of non-zero elements in the off-diagonal locations. From the graph point of view, we eliminate that node next which has minimum degree. This algorithm, even though, being more complex than the first one, is certainly more efficient because it takes into account the changes in the pattern of non-zero elements in the process of elimination.

3. In this algorithm, in the process of elimination, eliminate that row next whose elimination will introduce minimum number of non-zero elements in the off diagonal locations. From the graph point of view in the process of elimination, eliminate that node next whose elimination will introduce minimum number of new links in the system graph. This algorithm has not been used by us because it takes more time compared to (2). However, if the criteria is only to optimize the computer memory with cost having no consideration, this is certainly the best.

Algorithm (2) which claims to optimize both the computer memory and almost the computer time has been used by us. The input information in this case is a list by rows of the column numbers counting off diagonal non-zero terms (i.e. branches). This scheme no doubt is more efficient than the first one.

# CHAPTER 4

# LOAD FLOW ANALYSIS: CASE STUDIES

## 4.1 INTRODUCTION:

This chapter presents the load flow studies for the following systems.

1. 14 bus 20 lines IEEE system
2. 57 bus 80 lines IEEE system
3. 100 bus 128 lines UPSEB systems

These systems have been studied using the following methods.

1. Newton-Raphson method in polar coordinates
2. Decoupled method in polar coordinates
3. Fast Decoupled method

The choice of a particular method invariably depends upon the following factors.

1. Memory requirement
2. Speed
3. Accuracy

and 4. Convergence criterion

An attempt has been made in this chapter to compare the three methods based upon above mentioned criterion. The results of the systems studied and their significance are also discussed. The details of the study have been categorized method-wise.

Memory requirement and computer time invariably dictate the choice of method for load flow studies i.e. why NR method in polar coordinates has been chosen.

Accuracy and quadratic convergence properties of this method are offset by the memory and computational requirement Although programming technique is important in all load flow methods for obtaining fast execution and economy in storage, it is the cornerstone of methods such as Newton - Raphson. Thus in the case sparsity oriented programming makes all the difference, for without efficient storage and execution this method loses all its charm. To emphasize on the importance of sparsity oriented programming for these methods (especially NR method) two sets of programs are developed.

SET I: Full storage mode and gaussian elimination for solving the load flow equations.

SET II: Storing only non-zero elements of the Jacobian and Bus admittance matrix and ordered elimination of the load flow equations.

Each of the above mentioned sets offers a choice of three methods viz Newton-Raphson, Decoupled and Fast Decoup The details of memory requirement and computation time for method [for the systems studied] with and without sparsity oriented programming are given. Each method will be taken

up and studied with reference to the four factors mentioned before. The results of the sample systems are used as a means of comparing various criteria's.

4.2 NEWTON-RAPHSON METHOD :

The three systems are solved using this method. The Computation time for different systems (with and without the use of sparsity oriented programming) are listed in Table 4.1. If we consider the 14 bus system and compare the per iteration time in Case I and Case II we find that the difference does not justify the extra efforts involved in sparsity oriented programming, but a glance at the results for 57 bus and 100 bus system will speak otherwise. The iteration time in Case I is roughly five times that of Case II for a 57 bus system and twenty five times for a 100 bus system respectively.

The saving in terms of memory requirement is also tremendous. Table 4.2 gives the memory saved with sparsity oriented approach. [Only Jacobian and bus admittance matrix requirements are compared as they take the bulk of storage space. The data storage requirements being same for both cases].

The memory requirement and computation time per iteration for case II increases linearly with the number of buses. In contrast to this, for case I the memory requirement is

Table 4.1

14 bus system

| Type | C.P.U. Time | No. of Iterations | Time per Iteration | Specified Tolerance $\epsilon$ | Achieved Tolerance |
|---|---|---|---|---|---|
| Without Sparsity (Case I) | 1.19 | 3 | 0.396 | 0.001 | 0.00011 |
| With Sparsity (Case II) | 0.95 | 3 | 0.316 | 0.001 | 0.00011 |

57 bus system

| Type | C.P.U. Time | No. of Iterations | Time per Iteration | Specified Tolerance $\epsilon$ | Achieved Tolerance |
|---|---|---|---|---|---|
| Without Sparsity (Case I) | 34.02 | 4 | 8.505 | 0.001 | 0.00015 |
| With Sparsity (Case II) | 6.98 | 4 | 1.745 | 0.001 | 0.00015 |

100 bus system

| Type | C.P.U. Time | No. of Iterations | Time per Iteration | Specified Tolerance $\epsilon$ | Achieved Tolerance |
|---|---|---|---|---|---|
| Without Sparsity (Case I) | 624.84 | 7 | 89.26 | 0.001 | 0.00015 |
| With Sparsity (Case II) | 25.80 | 7 | 3.69 | 0.001 | 0.00015 |

Table 4.2

| No. of buses | No. of P-V buses | Order of Jacobian | Order of $Y_{Bus}$ | Without Sparsity (Case I) | | | With Sparsity (Case II) | | | Saving | % sav. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jacobian | $Y_{Bus}$ | Total | Jacobian* | $Y^*_{Bus}$ | Total | | |
| 14 | 5 | 22 | 14 | 484 | 392 | 876 | 438 | 216 | 654 | 222 | 25.34 |
| 57 | 7 | 106 | 57 | 11236 | 6498 | 17734 | 2154 | 852 | 3006 | 14728 | 83.05 |
| 100 | 19 | 180 | 100 | 32400 | 20000 | 52400 | 3702 | 1424 | 5126 | 47274 | 90.22 |

*This includes the storage needed for indexing information.

Table 4.3

14 bus system

| Type | C.P.U. Time | Iterations | Time per Iteration | Specified $\epsilon_S$ | Achieved $\epsilon_A$ |
|---|---|---|---|---|---|
| Without Sparsity (Case I) | 3.0 | 15 | 0.2 | 0.001 | 0.00097 |
| With Sparsity (Case II) | 2.16 | 15 | 0.144 | 0.001 | 0.00097 |

57 bus system

| Type | C.P.U. Time | Iterations | Time per Iteration | Specified $\epsilon_S$ | Achieved $\epsilon_A$ |
|---|---|---|---|---|---|
| Without Sparsity (Case I) | 14.56 | 7 | 2.08 | 0.06 | 0.051 |
| With Sparsity (Case II) | 10.38 | 7 | 1.48 | 0.06 | 0.051 |

100 bus system

| Type | C.P.U. Time | Iterations | Time per Iteration | Specified $\epsilon_S$ | Achieved $\epsilon_A$ |
|---|---|---|---|---|---|
| Without Sparsity (Case I) | 75.54 | 9 | 8.4 | 0.001 | 0.00048 |
| With Sparsity (Case II) | 32.0 | 9 | 3.56 | 0.001 | 0.00048 |

Table 4.4

| No. of buses | No. of P-V buses | Order of Jacobian | Order of $Y_{Bus}$ | Without Sparsity (Case I) | | | With Sparsity (Case II) | | | Saving | % sav |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jacobian | $Y_{Bus}$ | Total | Jacobian* | $Y^*_{Bus}$ | Total | | |
| 14 | 5 | 13 | 14 | 169 | 392 | 561 | 147 | 216 | 363 | 198 | 35.29 |
| 57 | 7 | 56 | 57 | 3136 | 6498 | 9634 | 612 | 852 | 1464 | 8170 | 84.8 |
| 100 | 19 | 99 | 100 | 9801 | 20000 | 29801 | 1059 | 1424 | 2483 | 27318 | 91.6 |

*This includes the storage needed for indexing information.

roughly $5N^2$, where N is the number of buses. From the Table 4.1 and 4.2, it can be inferred that the Newton-Raphson method realizes its full potential only when it is used with sparsity ordered elimination, especially for a large scale system.

4.3 DECOUPLED METHOD:

Table 4.3 gives the computation time for the three syst It is interesting to note that the decoupled technique, saves substantial amount of time, compared to Newton-Raphson method, for Case I, (compare tables 4.1 and 4.3 for Case I) but this saving is almost negligible when we compare for Case II, e.g. for 100 bus system, the iteration time for the Newton-Raphson method (case II) is 3.69 seconds while the corresponding time for Decoupled technique (case II) is 3.56 seconds. Table 4.4 gives the memory requirements for the Decoupled method. A comparison of Table 4.2 and Table 4.4, reveals the following.

For Case I : 100 bus system , Decoupled method requires 29801 words of memory as compared to 52400 in Newton-Raphson method. This amounts to a saving of 50%.

For case II : 100 bus system; Decoupled method requires 2473 words as compared to 5126 in Newton-Raphson method.

Although, the saving in this case is of the order of about 40% , its significance is not much because the absolute memory requirement has come down to a low level because of sparsity. Thus, when the sparsity and ordered eliminates are used, the Decoupled method is ruled out because memory requirement and computer time are almost same for both methods, hence one would prefer to make use of the more accurate method like Newton-Raphson with the added advantage of quadratic convergence (true quadratic convergence characteristics is lost in the Decoupled method ).

## 4.4 FAST DECOUPLED METHOD:

Tables 4.5 and 4.6 give the computation time and memory requirement for the three systems. In this method, the iteration time is reduced to a great extent as compared with other methods. Memory requirements for this method are the same as that for Decoupled method. Quadratic convergence feature is lost in this method and thus we need a few additional iterations for convergence as compared to Newton-Raphson However the increase in overall time is not much because of the lower per iteration time.

## 4.5 Q LIMIT ADJUSTMENT:

Q limit adjustment is also tried out using the following three schemes.

Table 4.5

14 bus system

| Type | C.P.U. Time | Iterations | Time per Iteration | Specified $\epsilon_S$ | Achieved $\epsilon_A$ |
|---|---|---|---|---|---|
| Without Sparsity (Case I) | 1.38 | 10 | 0.138 | 0.001 | 0.00080 |
| With Sparsity (Case II) | 1.22 | 10 | 0.122 | 0.001 | 0.00080 |

57 bus system

| Type | C.P.U. Time | Iterations | Time per Iteration | Specified $\epsilon_S$ | Achieved $\epsilon_A$ |
|---|---|---|---|---|---|
| Without Sparsity (Case I) | 9.76 | 6 | 1.626 | 0.02 | 0.019 |
| With Sparsity (Case II) | 5.28 | 6 | 0.88 | 0.02 | 0.019 |

100 bus system

| Type | C.P.U. Time | Iterations | Time per Iteration | Specified $\epsilon_S$ | Achieved $\epsilon_A$ |
|---|---|---|---|---|---|
| Without Sparsity (Case I) | 52.57 | 7 | 7.51 | 0.001 | 0.00028 |
| With Sparsity (Case II) | 14 | 7 | 2.0 | 0.001 | 0.00028 |

Table 4.6

| No. of buses | No. of P-V buses | Order of Jacobian | Order of $Y_{Bus}$ | Without Sparsity (Case I) | | | With Sparsity (Case II) | | | Saving | % sav. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jacobian | $Y_{Bus}$ | Total | Jacobian* + | $Y^*_{Bus}$ | Total | | |
| 14 | 5 | 13 | 14 | 169 | 392 | 561 | 324 | 216 | 540 | 21 | 3.7% |
| 57 | 7 | 56 | 57 | 3136 | 6498 | 9634 | 1278 | 852 | 2130 | 7504 | 77.9% |
| 100 | 19 | 99 | 100 | 9801 | 20000 | 29801 | 2136 | 1424 | 3560 | 26241 | 88.05% |

*This includes storage needed for indexing information.

+In case Table of factors for both B' and B'' are stored. (If Table of factors B' and B'' are not stored then memory requirement is almost the same as that for Decoupled method).

1. P-V to P-Q switching
2. Voltage perturbation
3. Voltage perturbation using feedback

The flow chart for the above mentioned methods are attached alongwith.

All these have not worked out very neatly. P-V to P-Q switching scheme works well for the 57 bus system, probably because of the number of P-V buses is not very large. When applied to the 100 bus system with 19 P-V buses (including slack) violations keep occuring at every iteration and the solution does not converge. The addition of soft constraints reduced the number of violations but without appreciable overall gain. In the voltage perturbation method the voltage of the P-V bus is perturbed slightly to 0.1% for 57 bus and 0.5% for 100 bus system to adjust the Q limits. The bus is treated as a P-V bus throughout. In this case convergence is obtained in an iteration when Q is being violated at one of the buses (bus No. 73 for the 100 bus case). Also, the Q at other P-V buses goes too far inside the Q limits.

In the third scheme, although the Q at most of the buses is within the tolerance band, yet, at one of the buses it is completely out of limit. This is because, the solution converges when the Q violation takes place at one of the

bus. If we introduce the constraint that both should be satisfied simultaneously then it does not converge at all.

All the schemes (1,2,and 3) have been tried out only in the case of Newton-Raphson method.

It is clear that the success in all the above schemes especially schemes 2 and 3 is due to various empirical adjustments. At the same time, the adjustments are system dependent i.e. they may work for a particular system only (this is true for voltage perturbation scheme no. 2).

The flow diagrams data and load flow results for the three systems by various methods have been attached alongwith. It is to be noted that for the 100 bus problem, results are for the adjusted solution with scheme (3). An unadjusted solution takes 4 iterations (Q's being violated at 6 buses) and 16.6 seconds. The results with Decoupled and Fast Decoupled methods using scheme 2, are also inclosed. It is to be noted that the unadjusted solution will require lesser number of iterations.

## CHAPTER 5

## CONCLUSION

The main objective of this thesis has been to present a detailed comparative study of Newton-Raphson, Decoupled and Fast Decoupled methods. The importance of any load flow solution depends largely upon its merits regarding reliability, convergence characteristics, solution time and memory requirements. The above methods differ, most, in their memory and computation time requirements. Keeping this in view, a comparative study of the aforementional methods has been made. In order to optimize computational time, the emphasis has been on the sparsi oriented programming approach. From the results obtained in this thesis, it is clear that this approach optimizes memory and/or computational time. The full potential of these methods is realized only when memory and computation time are optimized by the application of sparsity oriented programming techniques.

For practical power system, various additional features, should be incorporated in the load flow program. These additional features are in the form of Q limits, variable transformer taps etc. The schemes tried out here for the Q limit, have not yielded satisfactory results. It is felt that the addition of these features in the load flow program would further enhance its utility.

# REFERENCES

[1] J.B. Ward and H.W. Hale, 'Digital Computer Solution of Power-flow Problems', AIEE Trans. (Power App. Syst.), vol. 75, pp. 398-404, June,1956.

[2] A.F. Glimn and G.W. Stagg, 'Automatic Calculation of Load-flows', AIEE Trans. (Power App. Syst.), vol. 76, pp. 817-828, Oct. 1957.

[3] J.E. Van Ness, 'Iteration Methods for Digital Load Flow Studies', AIEE Trans. (Power App. Syst.), vol. 78, pp. 583-588, Aug. 1959.

[4] J.E. Van Ness and J.H. Griffin, 'Elimination Methods for Load-flow Studies', AIEE Trans. (Power App. Syst.), vol. 80, pp. 299-304, June,1961.

[5] W.F. Tinney and J.W. Walker, 'Direct Solutions of Sparse Network Equations by Optimally Ordered Triangular Factorization', Proc. IEEE, vol. 55, pp. 1801-1809, Nov. 1967.

[6] W.F. Tinney and C.E. Hart, 'Power Solution by Newton's Method', IEEE Trans. (Power App. Syst.), vol. PAS-86, pp. 1449-1456, Nov. 1967.

[7] Brian Stott, 'Review of Load-flow Calculation Methods', Proc. IEEE, vol. 62, No. 7, pp. 916-929, July,1974.

[8] B. Stott and O. Alsac, 'Fast Decoupled Load-flow', IEEE Trans. on PAS, vol. 93, pp. 859-864, 1974.

[9] W.F. Tinny and N. Sato, 'Technique for Exploiting the Sparsity of Newton's Method', IEEE Trans. on PAS, vol. 82, pp. 944, Dec., 1963.

[10] L.P. Singh and A.K. Goel, 'An Optimal Ordering for Sparse System', JIE(India), vol. 57, Pt. EL-2, pp. 105, Oct. 1976.

[11] L.P. Singh and H.C. Sirivastava, 'Sparsity and Optimal Ordering', JIE(India), vol. 57, Pt. EL-6, pp. 274, June 1977.

[12] K.K. Goyal and L.P. Singh, 'Optimal Elimination of Sparse System using Dynamic Programming Technique', Proc. CST-81, March 14, 1981, N.D.

[13] M.A. Pai, 'Computer Techniques in Power System Analysis', New Delhi : McGraw Hill 1979.

[14] Olle I. Elgerd, 'Electric Energy Systems Theory', New Delhi : McGraw Hill 1971.

[15] G.W. Stagg and A.H. El-Abiad, 'Computer Methods in Power System Analysis', New York: McGraw Hill, 1968.

## APPENDIX

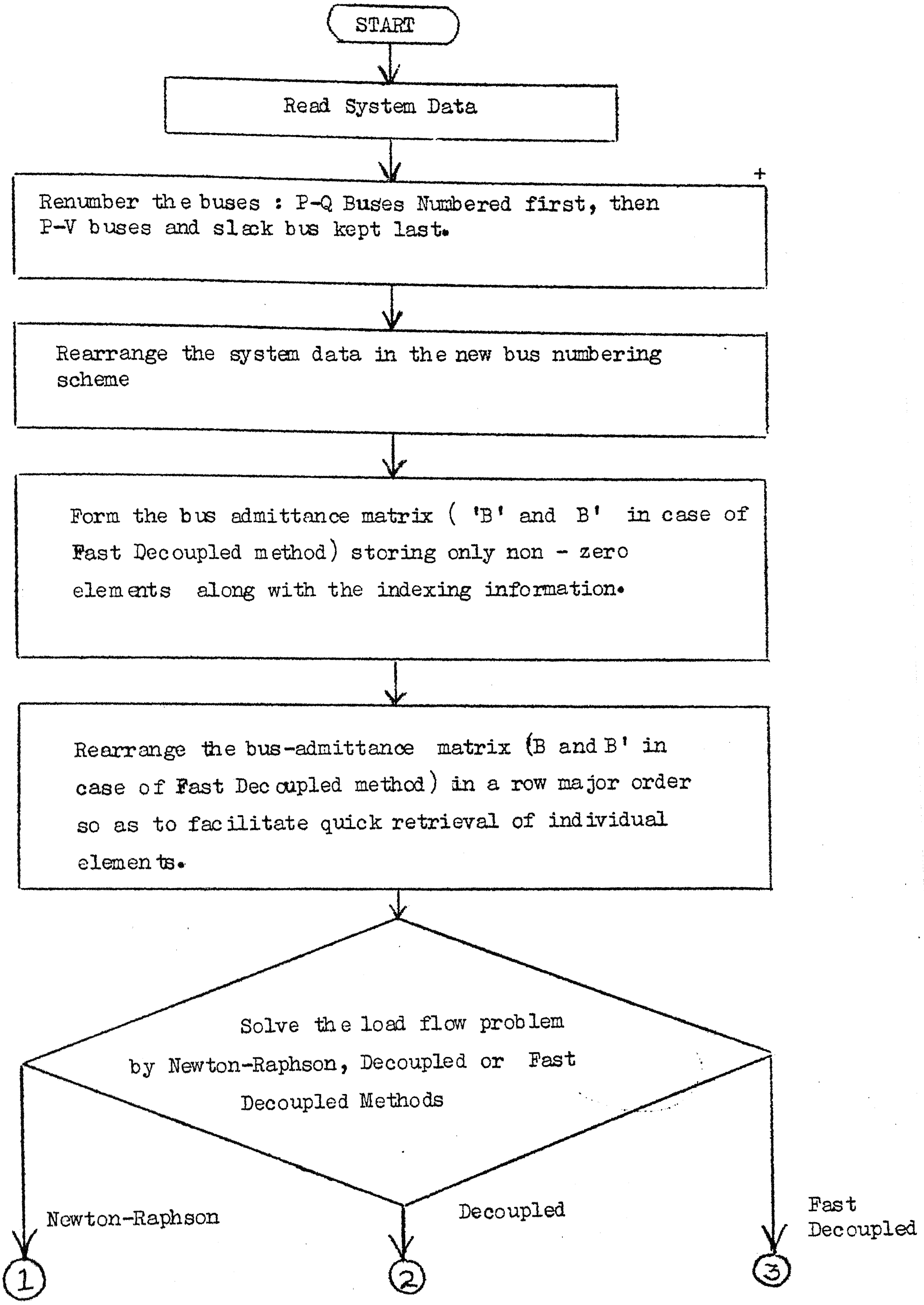
The general 'continuous feedback' adjustment formula is

$$\Delta x = \alpha \Delta Y$$

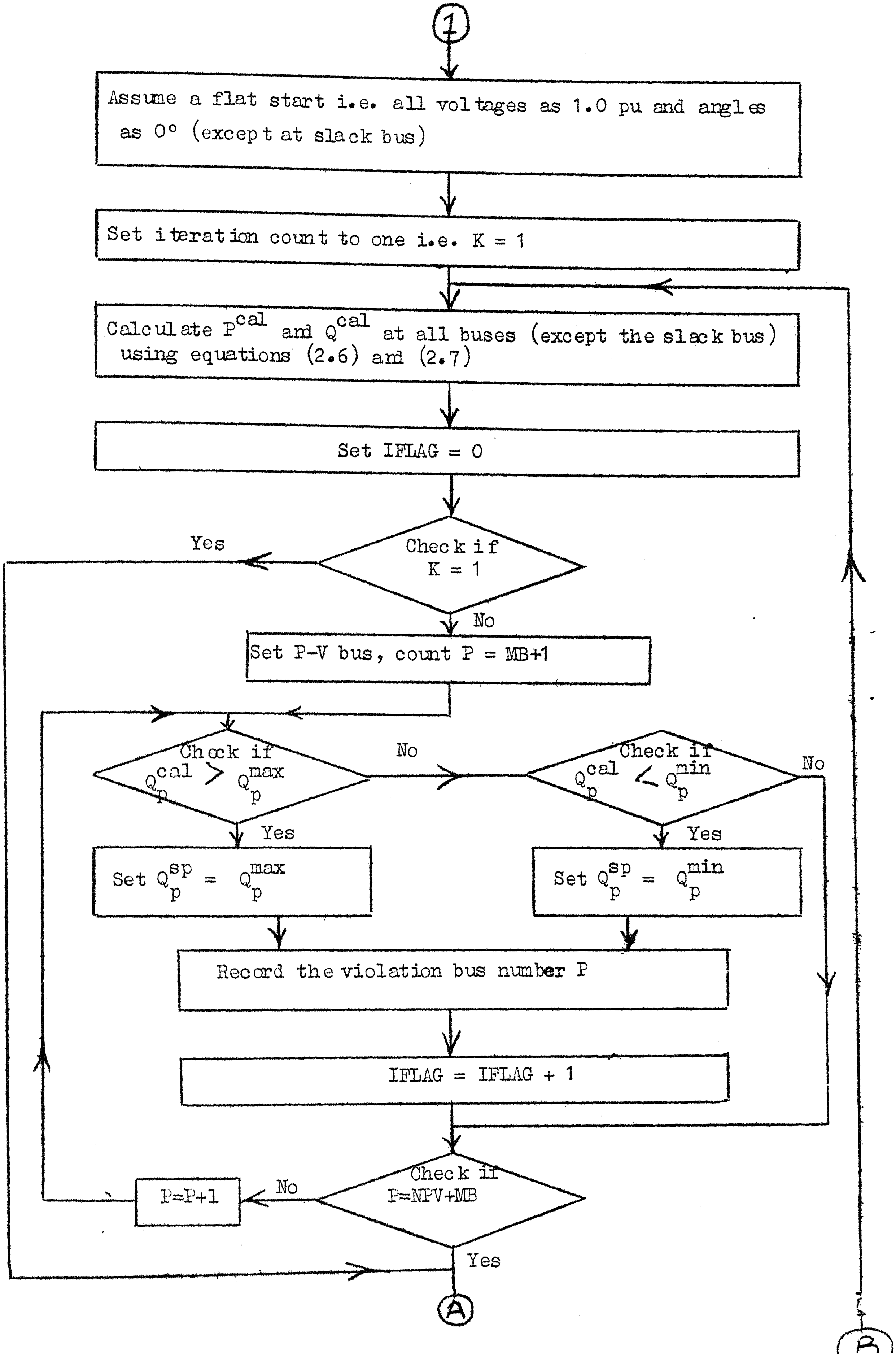
where $\alpha$ is the 'feedback gain' whose choice is important fc each type of control, each load flow method, and in some cases each system. The objective in choosing $\alpha$ is to minimise the total number of iterations while preserving reliable convergence. The slowly converging methods tend to suffer much less than the fast converging ones from the effects of the adjustments. The value of $\alpha$ can be choosen empirically to suit a particular system or else should be approximately the sensitivity between x and y at the operating point. For a given system, a suitable fixed estimate of this can be calculated or found empirically.

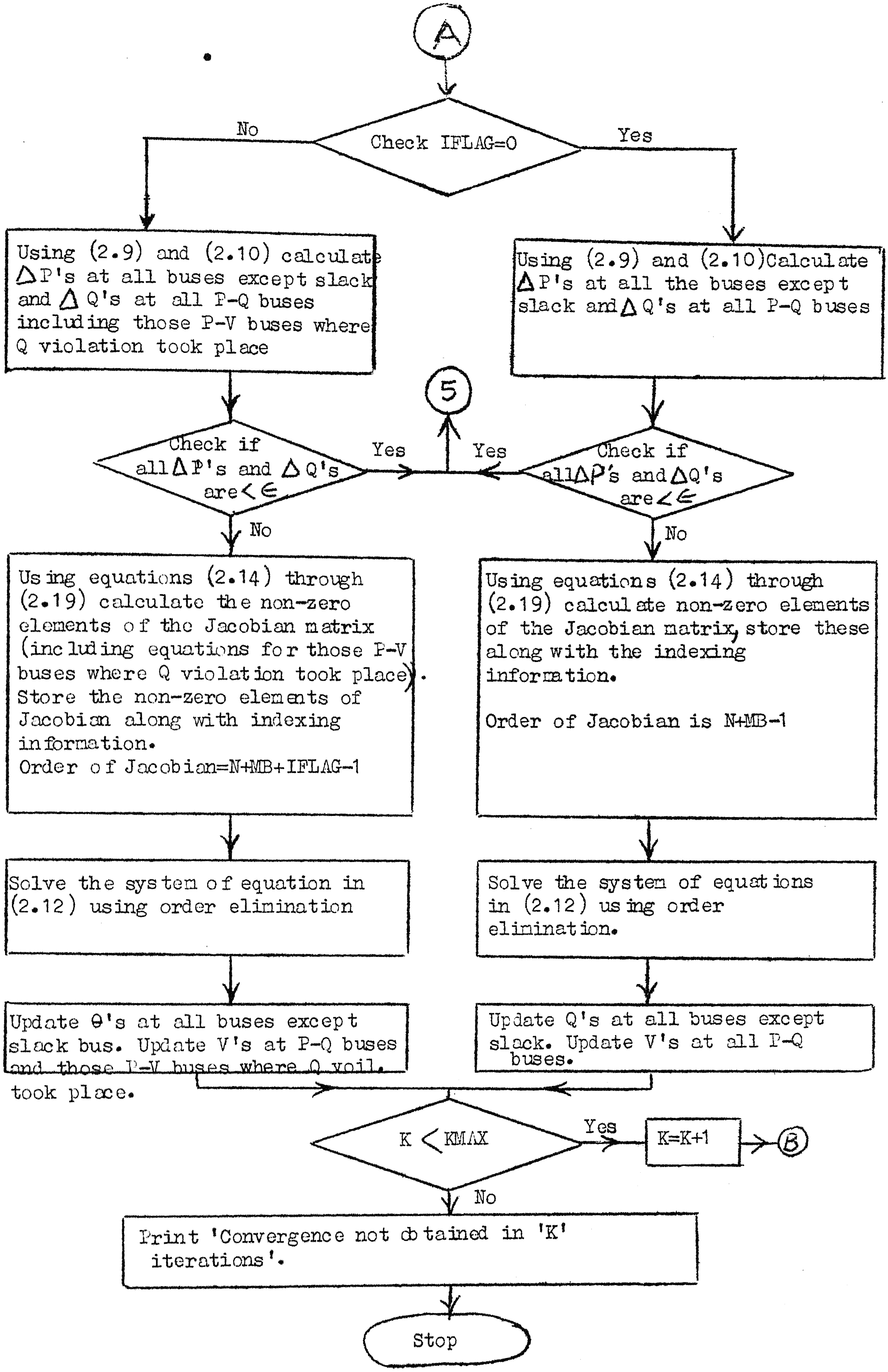
When the adjustment process is initiated, a trial correction $\Delta x^{(1)}$ (not too small) is made on the basis of an error $\Delta y^{(0)}$. One or more load flow iterations are then performed until moderate convergence is achieved, and the new error is $y^{(1)}$. An estimate of $\alpha$ can now be found thus,

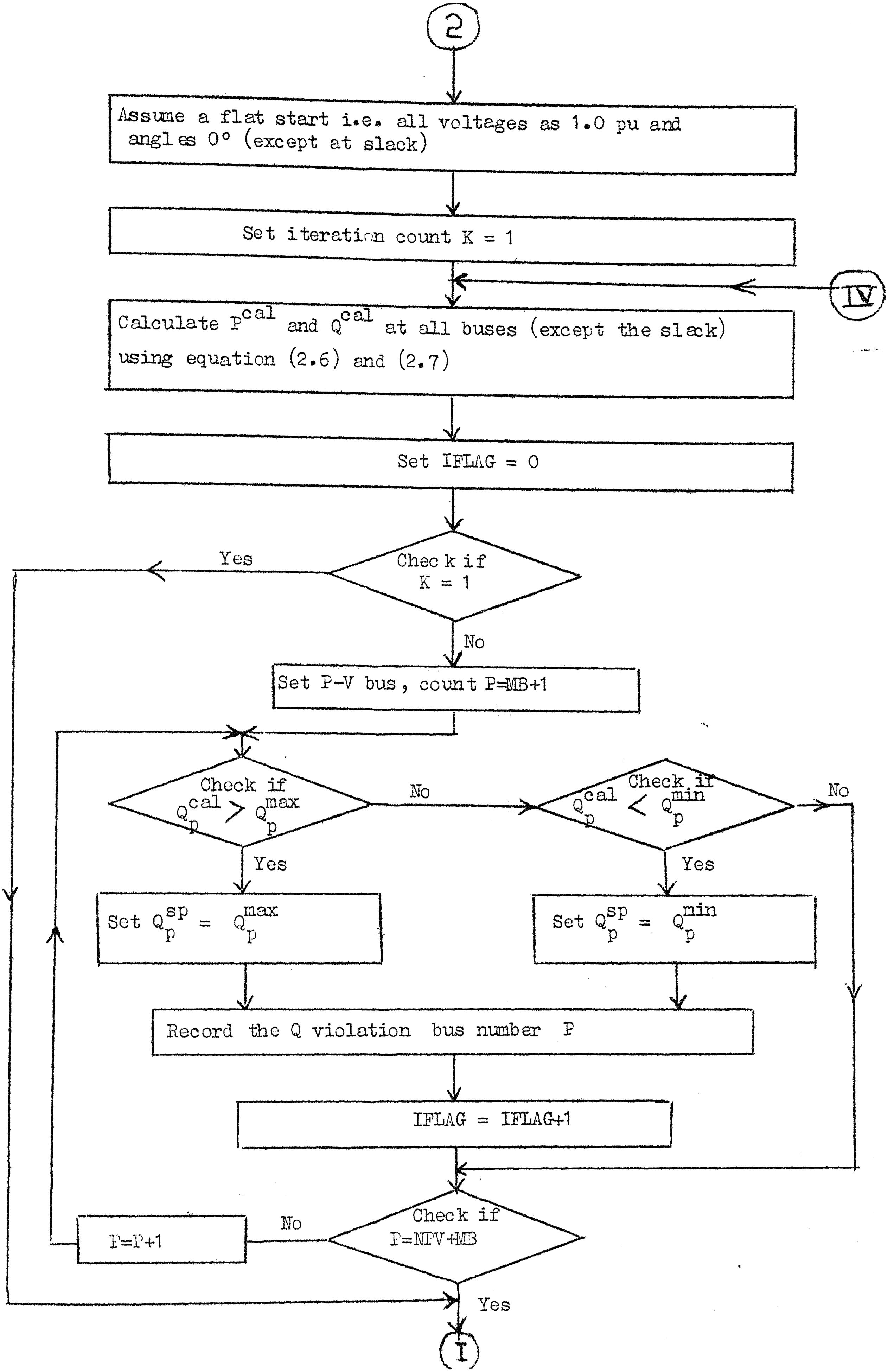
$$\alpha = \Delta x^{(1)}/(\Delta y^{(1)} - \Delta y^{(0)})$$

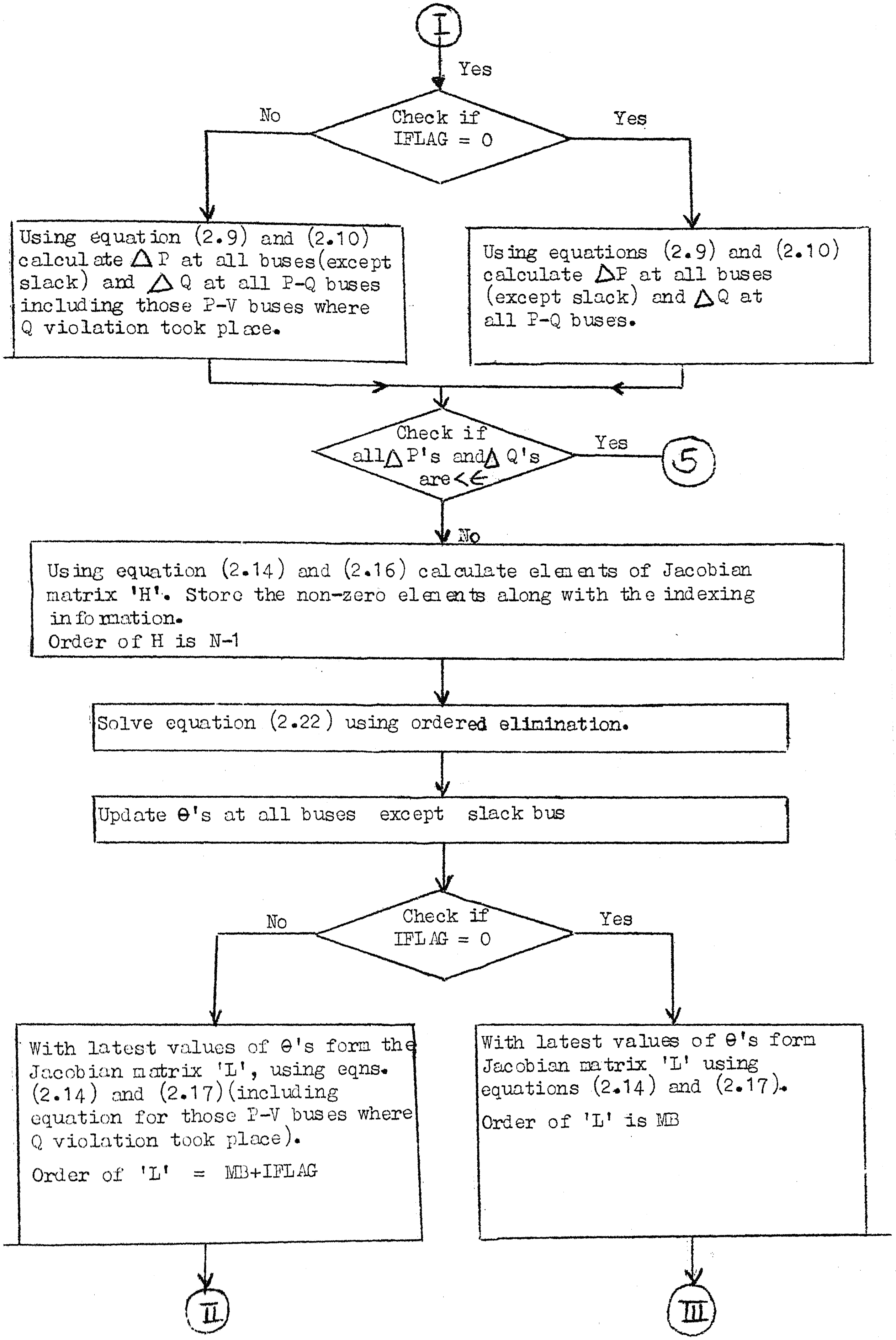


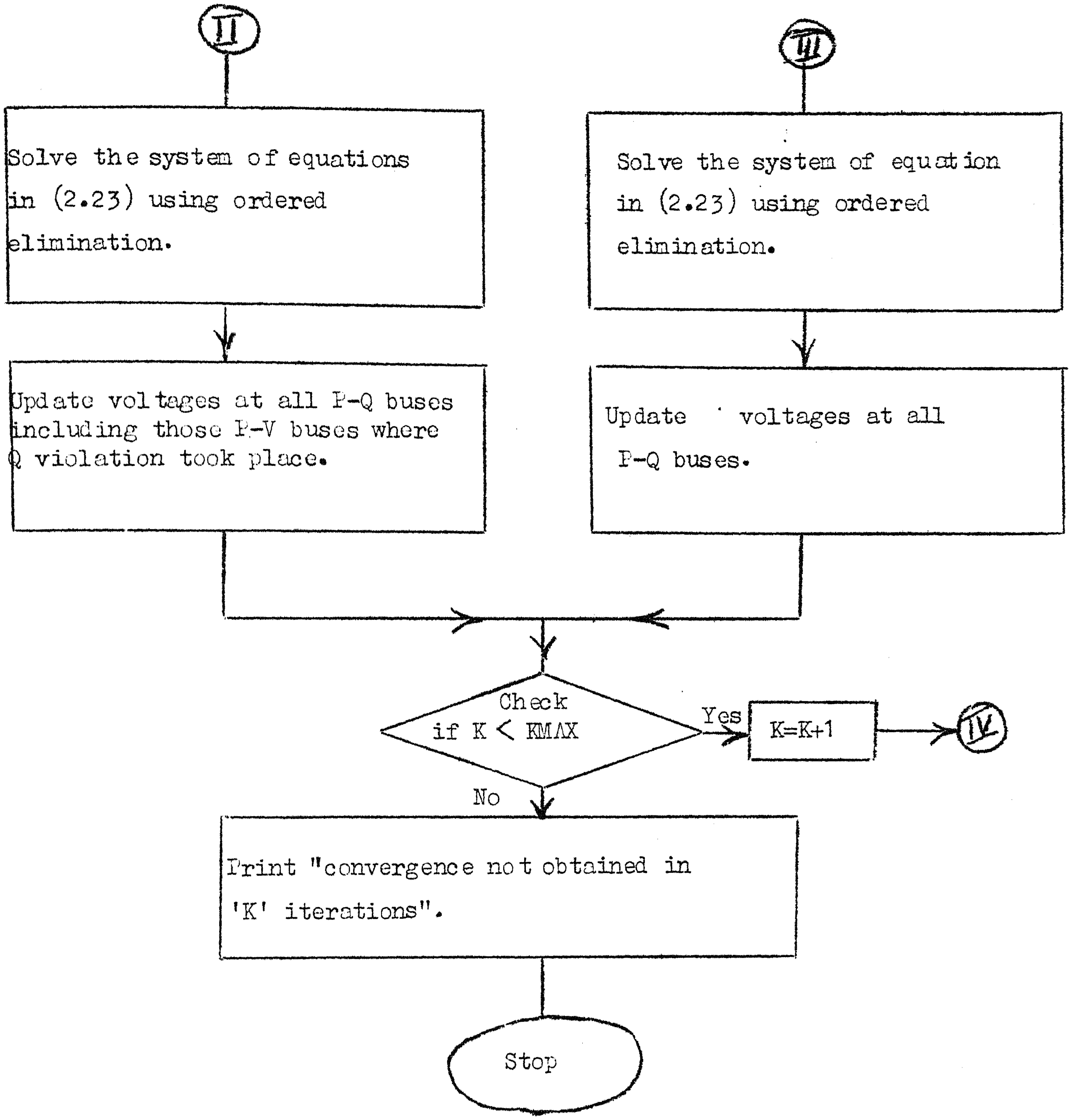

Flow Chart for the Newton-Raphson, Decoupled and Fast Decoupled methods using Sparsity and ordered elimination.

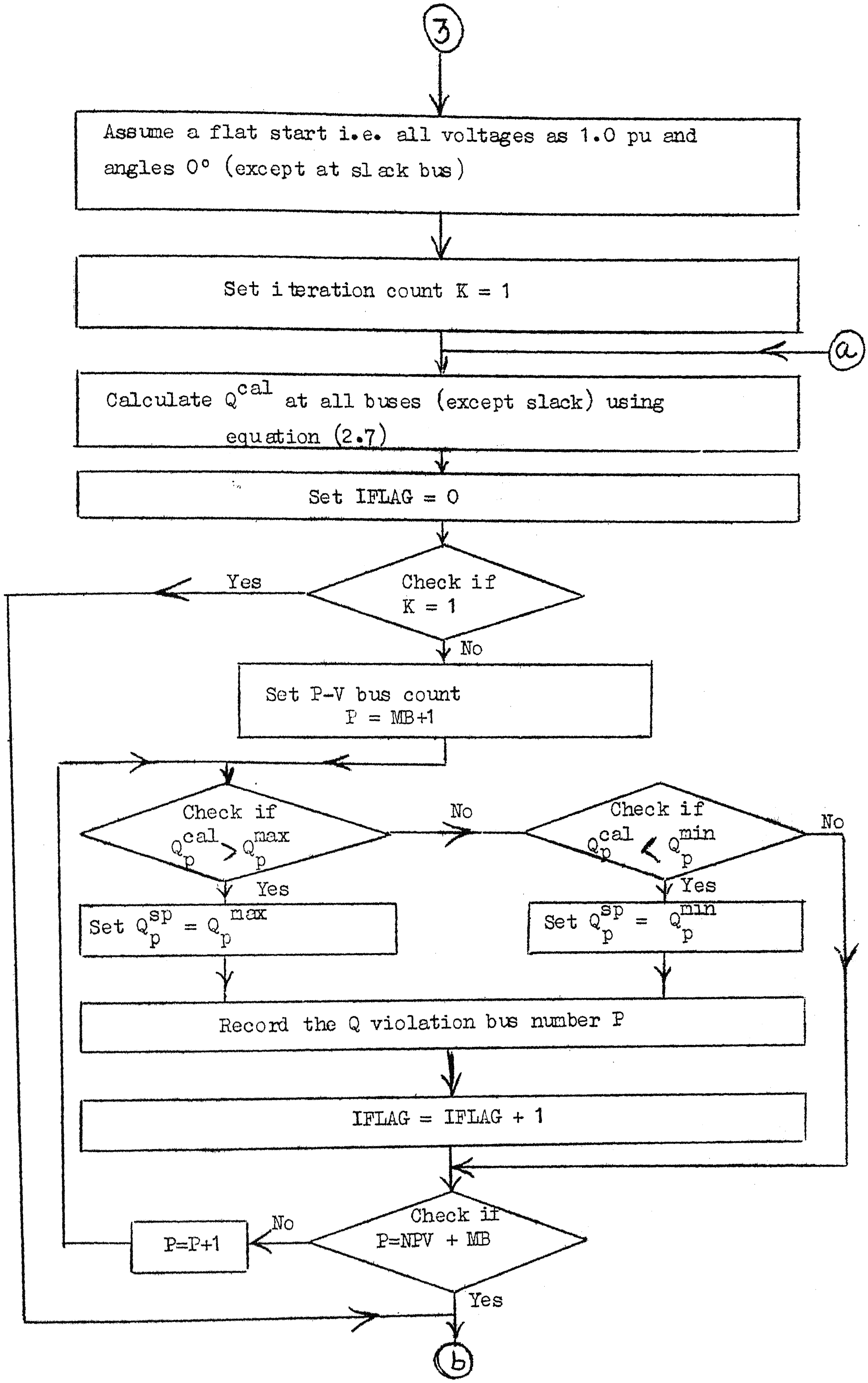

1
Assume a flat start i.e. all voltages as 1.0 pu and angles as 0° (except at slack bus)
Set iteration count to one i.e. K = 1
Calculate $P^{cal}$ and $Q^{cal}$ at all buses (except the slack bus) using equations (2.6) and (2.7)
Set IFLAG = 0
Check if K = 1
Yes
No
Set P-V bus, count P = MB+1
Check if $Q_p^{cal} > Q_p^{max}$
No
Yes
Check if $Q_p^{cal} < Q_p^{min}$
No
Yes
Set $Q_p^{sp} = Q_p^{max}$
Set $Q_p^{sp} = Q_p^{min}$
Record the violation bus number P
IFLAG = IFLAG + 1
Check if P=NPV+MB
No
P=P+1
Yes
A
B

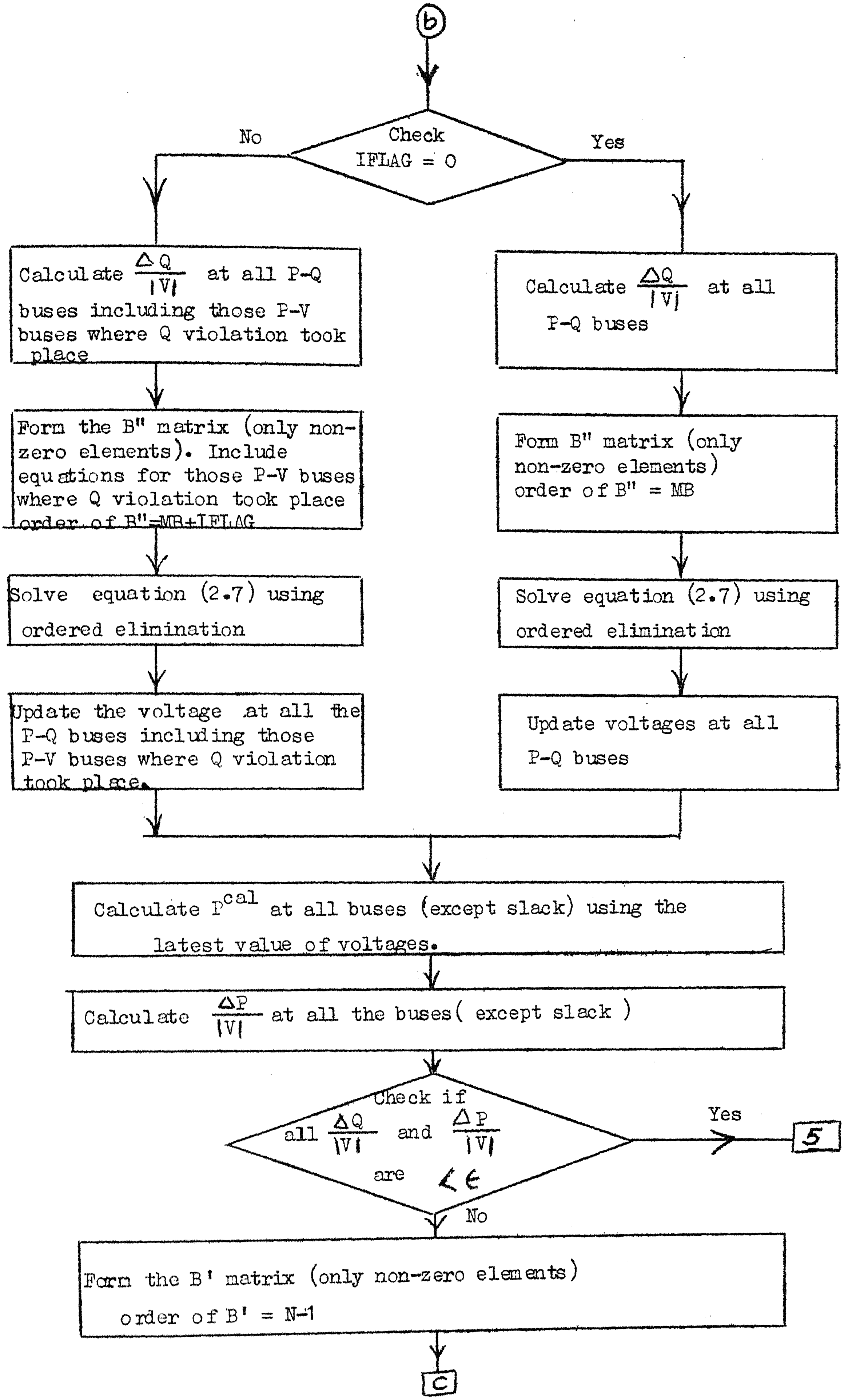

A
Check IFLAG=0
No
Yes
Using (2.9) and (2.10) calculate ΔP's at all buses except slack and ΔQ's at all P-Q buses including those P-V buses where Q violation took place
Using (2.9) and (2.10) Calculate ΔP's at all the buses except slack and ΔQ's at all P-Q buses
5
Check if all ΔP's and ΔQ's are < ∈
Yes
Yes
Check if all ΔP's and ΔQ's are < ∈
No
No
Using equations (2.14) through (2.19) calculate the non-zero elements of the Jacobian matrix (including equations for those P-V buses where Q violation took place). Store the non-zero elements of Jacobian along with indexing information.
Order of Jacobian=N+MB+IFLAG-1
Using equations (2.14) through (2.19) calculate non-zero elements of the Jacobian matrix, store these along with the indexing information.
Order of Jacobian is N+MB-1
Solve the system of equation in (2.12) using order elimination
Solve the system of equations in (2.12) using order elimination.
Update θ's at all buses except slack bus. Update V's at P-Q buses and those P-V buses where Q voil. took place.
Update Q's at all buses except slack. Update V's at all P-Q buses.
K < KMAX
Yes
K=K+1
B
No
Print 'Convergence not obtained in 'K' iterations'.
Stop

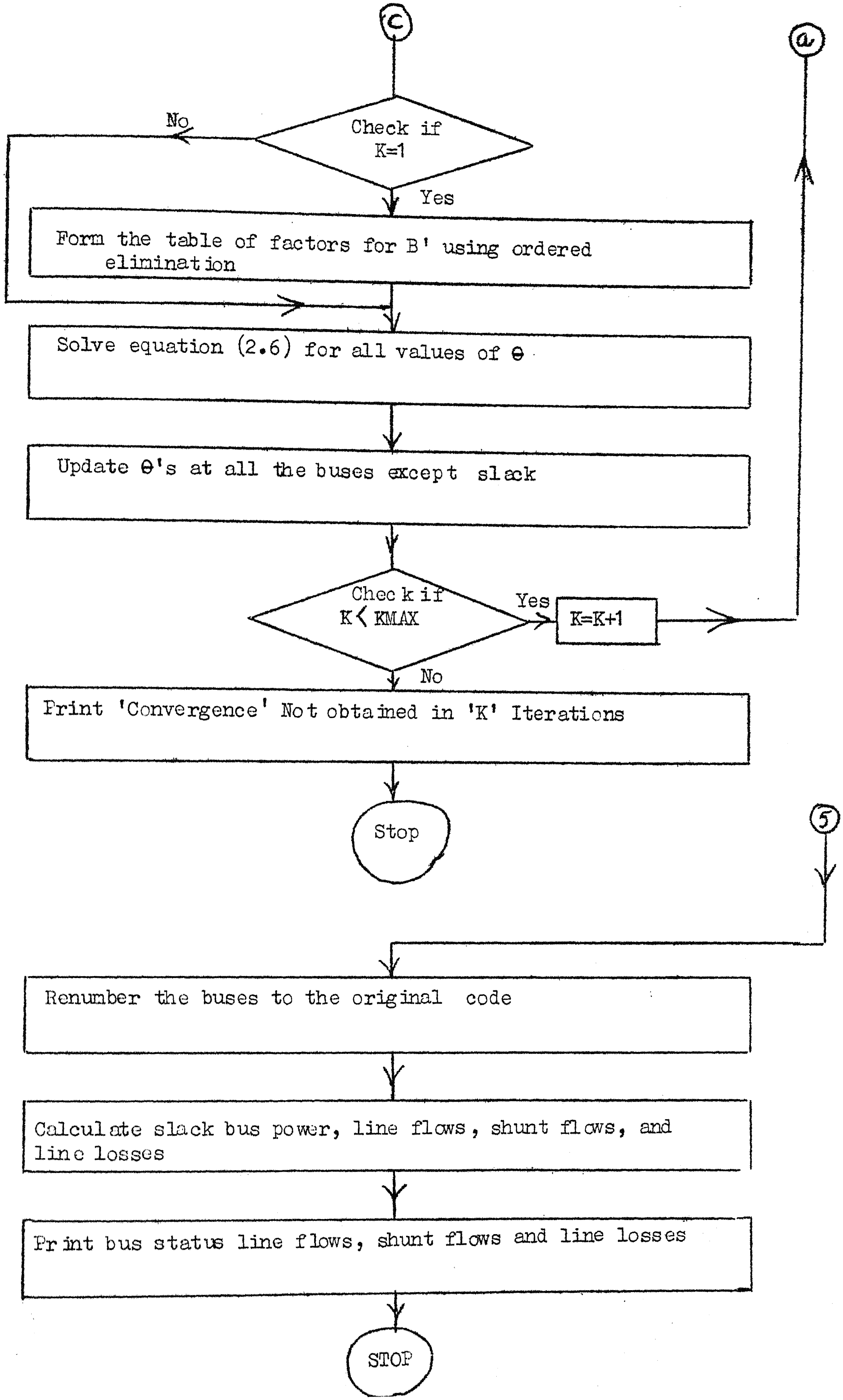

2
Assume a flat start i.e. all voltages as 1.0 pu and angles 0° (except at slack)
Set iteration count K = 1
IV
Calculate $P^{cal}$ and $Q^{cal}$ at all buses (except the slack) using equation (2.6) and (2.7)
Set IFLAG = 0
Check if K = 1
Yes
No
Set P-V bus, count P=MB+1
Check if $Q_p^{cal} > Q_p^{max}$
No
Check if $Q_p^{cal} < Q_p^{min}$
No
Yes
Yes
Set $Q_p^{sp} = Q_p^{max}$
Set $Q_p^{sp} = Q_p^{min}$
Record the Q violation bus number P
IFLAG = IFLAG+1
P=P+1
No
Check if P=NPV+MB
Yes
I

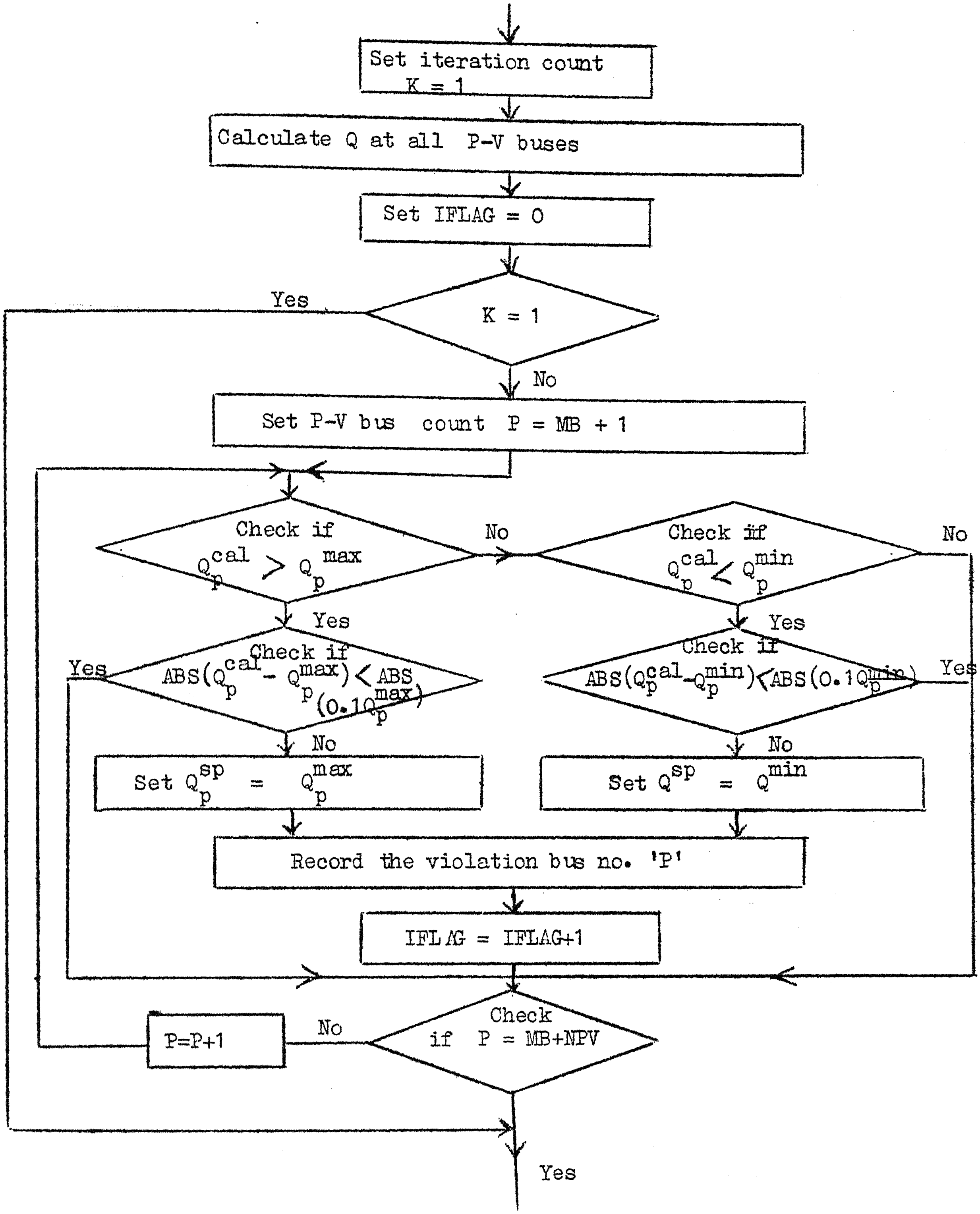

I
Yes
Check if IFLAG = 0
No
Yes
Using equation (2.9) and (2.10) calculate ΔP at all buses(except slack) and ΔQ at all P-Q buses including those P-V buses where Q violation took place.
Using equations (2.9) and (2.10) calculate ΔP at all buses (except slack) and ΔQ at all P-Q buses.
Check if all ΔP's and ΔQ's are <ϵ
Yes
5
No
Using equation (2.14) and (2.16) calculate elements of Jacobian matrix 'H'. Store the non-zero elements along with the indexing information.
Order of H is N-1
Solve equation (2.22) using ordered elimination.
Update θ's at all buses except slack bus
Check if IFLAG = 0
No
Yes
With latest values of θ's form the Jacobian matrix 'L', using eqns. (2.14) and (2.17)(including equation for those P-V buses where Q violation took place).
Order of 'L' = MB+IFLAG
With latest values of θ's form Jacobian matrix 'L' using equations (2.14) and (2.17).
Order of 'L' is MB
II
III


II
III
Solve the system of equations in (2.23) using ordered elimination.
Solve the system of equation in (2.23) using ordered elimination.
Update voltages at all P-Q buses including those P-V buses where Q violation took place.
Update voltages at all P-Q buses.
Check if K < KMAX
Yes
K=K+1
IV
No
Print "convergence not obtained in 'K' iterations".
Stop

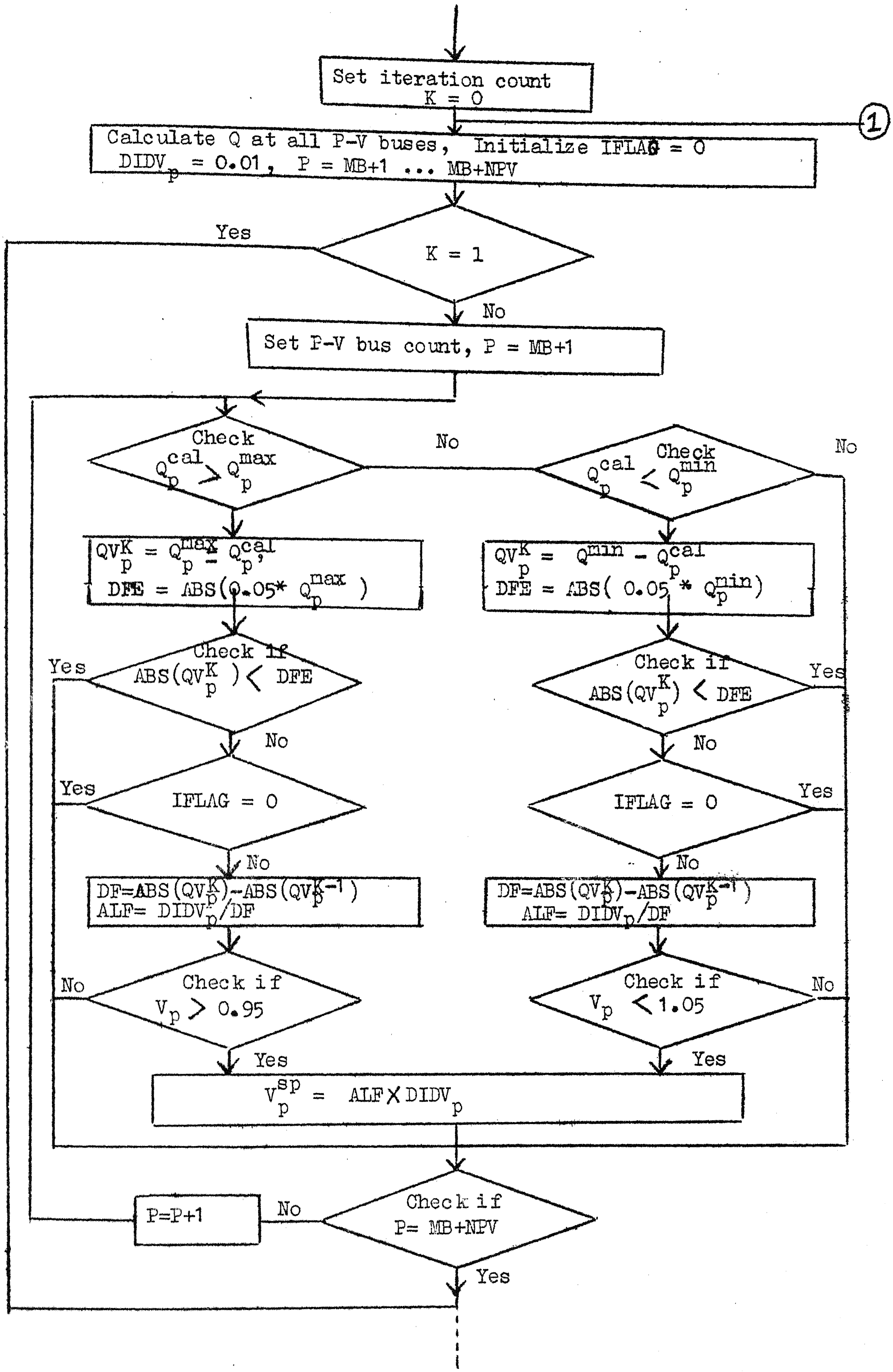

3
Assume a flat start i.e. all voltages as 1.0 pu and angles 0° (except at slack bus)
Set iteration count K = 1
a
Calculate $Q^{cal}$ at all buses (except slack) using equation (2.7)
Set IFLAG = 0
Check if K = 1
Yes
No
Set P-V bus count P = MB+1
Check if $Q_p^{cal} > Q_p^{max}$
No
Check if $Q_p^{cal} < Q_p^{min}$
No
Yes
Yes
Set $Q_p^{sp} = Q_p^{max}$
Set $Q_p^{sp} = Q_p^{min}$
Record the Q violation bus number P
IFLAG = IFLAG + 1
Check if P=NPV + MB
No
P=P+1
Yes
b


b
Check IFLAG = 0
No
Yes
Calculate ΔQ/|V| at all P-Q buses including those P-V buses where Q violation took place
Form the B" matrix (only non-zero elements). Include equations for those P-V buses where Q violation took place order of B"=MB+IFLAG
Solve equation (2.7) using ordered elimination
Update the voltage at all the P-Q buses including those P-V buses where Q violation took place.
Calculate ΔQ/|V| at all P-Q buses
Form B" matrix (only non-zero elements) order of B" = MB
Solve equation (2.7) using ordered elimination
Update voltages at all P-Q buses
Calculate P^cal at all buses (except slack) using the latest value of voltages.
Calculate ΔP/|V| at all the buses( except slack )
Check if all ΔQ/|V| and ΔP/|V| are < ε
Yes
5
No
Form the B' matrix (only non-zero elements) order of B' = N-1
c

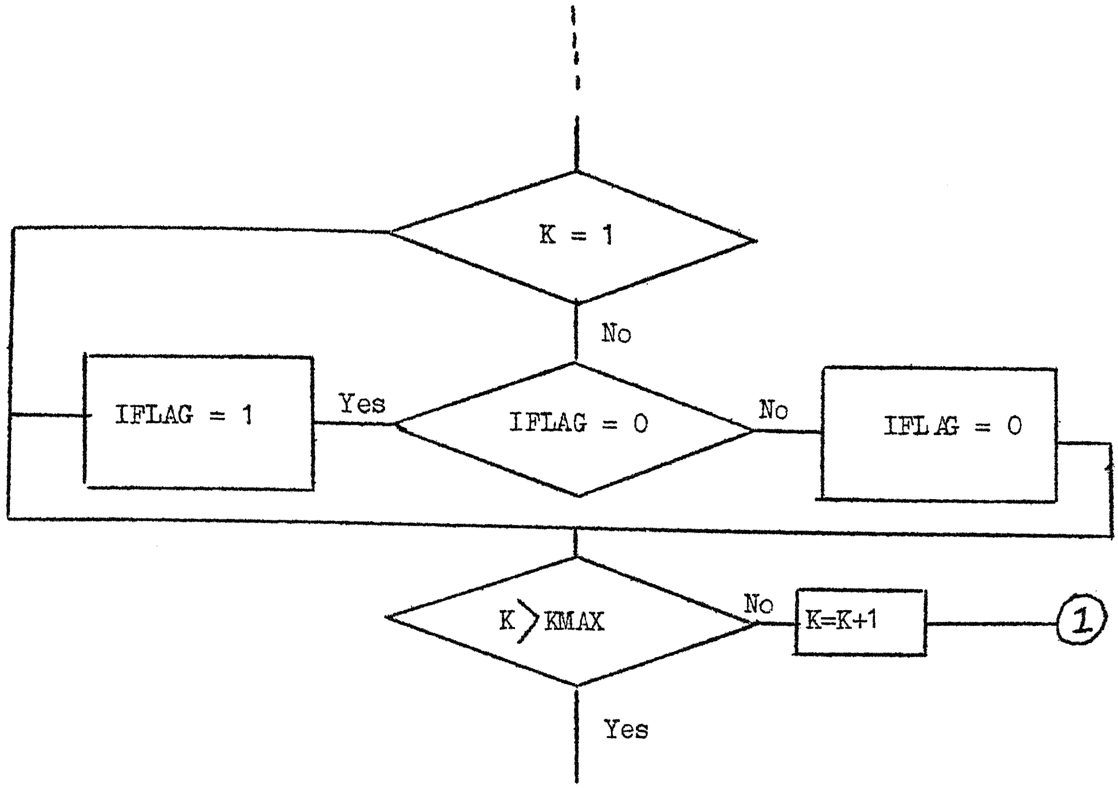

c
a
Check if K=1
No
Yes
Form the table of factors for B' using ordered elimination
Solve equation (2.6) for all values of θ
Update θ's at all the buses except slack
Check if K < KMAX
Yes
K=K+1
No
Print 'Convergence' Not obtained in 'K' Iterations
Stop
5
Renumber the buses to the original code
Calculate slack bus power, line flows, shunt flows, and line losses
Print bus status line flows, shunt flows and line losses
STOP




Q limits with P-V to P-Q switching (with soft constrants)



Set iteration count
K = 0
1
Calculate Q at all P-V buses, Initialize IFLAG = 0
DIDV$_p$ = 0.01, P = MB+1 ... MB+NPV
K = 1
Yes
No
Set P-V bus count, P = MB+1
Check
$Q_p^{cal} > Q_p^{max}$
No
Check
$Q_p^{cal} < Q_p^{min}$
No
$QV_p^K = Q_p^{max} - Q_p^{cal}$,
DFE = ABS(0.05* $Q_p^{max}$ )
$QV_p^K = Q^{min} - Q_p^{cal}$
DFE = ABS( 0.05 * $Q_p^{min}$)
Check if
ABS($QV_p^K$) < DFE
Yes
No
Check if
ABS($QV_p^K$) < DFE
Yes
No
IFLAG = 0
Yes
No
IFLAG = 0
Yes
No
DF=ABS($QV_p^K$)-ABS($QV_p^{K-1}$)
ALF= DIDV$_p$/DF
DF=ABS($QV_p^K$)-ABS($QV_p^{K-1}$)
ALF= DIDV$_p$/DF
Check if
$V_p$ > 0.95
No
Yes
Check if
$V_p$ < 1.05
No
Yes
$V_p^{sp}$ = ALF X DIDV$_p$
P=P+1
No
Check if
P= MB+NPV
Yes




Q-limits using error feed back principle with soft constraints

NOTE: For N bus system
Let P-Q buses = MB
and P-V Buses = NPV
(Not including slack)

Then after renumbering as in block two of flow chart.$^{+}$

Bus No. 1 to MB will be P-Q buses

Bus No. MB+1 to MB+NPV will be P-V buses

Bus No. MB+NPV+1 will be slack bus

IEEE 14 BUS SYSTEM FROM M.A.PAI

IPDATA = [illegible] ISWICH = [illegible] INETH = 3 ICHOIC = 0 ISTART = 0

NO. OF STUDIES = 1 PRINT OPTIONS = 2 2 2 2 2 2

## LIST OF INPUT DATA

| NO. OF BUSES | NO. OF LINES | SLACK BUS | VOLT. CONT BUSES | SHUNT LOADS | MAX. ITERATIONS | CONV. LIMIT | BASE POWER |
|---|---|---|---|---|---|---|---|
| 14 | 20 | 14 | 5 | 1 | 10 | .00100000 | 100.00 |

BUS DATA

| BUS NO. | NAME | GENERATION | | LOAD POWER | | ASSUMED BUS VOLTAGES VOLT MAG | PHASE ANGLE |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.0000 | 0.0000 | 14.9000 | 5.0000 | 1.0000 | 0.0000 |
| 2 | 2 | 40.0000 | 0.0000 | 21.7000 | 12.7000 | 1.0000 | 0.0000 |
| 3 | 3 | 0.0000 | 0.0000 | 94.2000 | 19.0000 | 1.0000 | 0.0000 |
| 4 | 4 | 0.0000 | 0.0000 | 47.8000 | 3.9000 | 1.0000 | 0.0000 |
| 5 | 5 | 0.0000 | 0.0000 | 7.6000 | 1.6000 | 1.0000 | 0.0000 |
| 6 | 6 | 0.0000 | 0.0000 | 11.2000 | 7.5000 | 1.0000 | 0.0000 |
| 7 | 7 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 8 | 8 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 9 | 9 | 0.0000 | 0.0000 | 29.5000 | 16.6000 | 1.0000 | 0.0000 |
| 10 | 10 | 0.0000 | 0.0000 | 9.0000 | 5.8000 | 1.0000 | 0.0000 |
| 11 | 11 | 0.0000 | 0.0000 | 3.5000 | 1.8000 | 1.0000 | 0.0000 |
| 12 | 12 | 0.0000 | 0.0000 | 6.1000 | 1.6000 | 1.0000 | 0.0000 |
| 13 | 13 | 0.0000 | 0.0000 | 13.5000 | 5.8000 | 1.0000 | 0.0000 |
| 14 | 14 | 232.4000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |

LINE DATA

| LINE NUMBER | FROM BUS | | TO BUS | | LINE IMPEDENCE | | HALF LINE CHARG ADMIT | | OFF NOM TR TURNS RATIO |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 14 | 14 | 2 | 2 | 0.01938 | 0.05917 | 0.00000 | 0.02640 | 1.00000 |
| 2 | 2 | 2 | 3 | 3 | 0.04699 | 0.19797 | 0.00000 | 0.02190 | 1.00000 |
| 3 | 2 | 2 | 4 | 4 | 0.05811 | 0.17632 | 0.00000 | 0.01870 | 1.00000 |
| 4 | 14 | 14 | 5 | 5 | 0.05403 | 0.22304 | 0.00000 | 0.02460 | 1.00000 |
| 5 | 2 | 2 | 5 | 5 | 0.05695 | 0.17388 | 0.00000 | 0.01700 | 1.00000 |
| 6 | 3 | 3 | 4 | 4 | 0.06701 | 0.17103 | 0.00000 | 0.01730 | 1.00000 |
| 7 | 4 | 4 | 5 | 5 | 0.01335 | 0.04211 | 0.00000 | 0.00640 | 1.00000 |
| 8 | 5 | 5 | 6 | 6 | 0.00000 | 0.25202 | 0.00000 | 0.00000 | 0.93200 |
| 9 | 4 | 4 | 7 | 7 | 0.00000 | 0.20912 | 0.00000 | 0.00000 | 0.97800 |
| 10 | 7 | 7 | 8 | 8 | 0.00000 | 0.17615 | 0.00000 | 0.00000 | 1.00000 |
| 11 | 4 | 4 | 9 | 9 | 0.00000 | 0.55618 | 0.00000 | 0.00000 | 0.96900 |
| 12 | 7 | 7 | 9 | 9 | 0.00000 | 0.11001 | 0.00000 | 0.00000 | 1.00000 |
| 13 | 9 | 9 | 10 | 10 | 0.03181 | 0.08450 | 0.00000 | 0.00000 | 1.00000 |
| 14 | 6 | 6 | 11 | 11 | 0.09498 | 0.19890 | 0.00000 | 0.00000 | 1.00000 |
| 15 | 6 | 6 | 12 | 12 | 0.12291 | 0.25581 | 0.00000 | 0.00000 | 1.00000 |
| 16 | 6 | 6 | 13 | 13 | 0.06615 | 0.13027 | 0.00000 | 0.00000 | 1.00000 |
| 17 | 9 | 9 | 1 | 1 | 0.12711 | 0.27038 | 0.00000 | 0.00000 | 1.00000 |
| 18 | 10 | 10 | 11 | 11 | 0.08205 | 0.19207 | [illegible] | | |
| 19 | 12 | 12 | [illegible] | | | | | | |

20 13 13 1 1 0.17093 0.[illegible]862 0.00000 0.00000 1.00000

VOLTAGE CONTROLLED BUS DATA

| S.NO. | BUS NO. | NAME | Q-MINIMUM | Q-MAXIMUM | SCHEDULED VOLTAGE |
|---|---|---|---|---|---|
| 1 | 2 | 2 | -40.0000 | 50.0000 | 1.0450 |
| 2 | 3 | 3 | 0.0000 | 40.0000 | 1.0100 |
| 3 | 6 | 6 | -6.0000 | 24.0000 | 1.0700 |
| 4 | 8 | 8 | -6.0000 | 24.0000 | 1.0900 |
| 5 | 14 | 14 | -50.0000 | 50.0000 | 1.0600 |

SHUNT LOAD DATA

| S.NO. | BUS NO. | NAME | SHUNT LOAD AVAILABLE | |
|---|---|---|---|---|
| 1 | 9 | 9 | 0.00000 | 0.19000 |

## LIST OF OUTPUT RESULTS

DMAX = 0.00010747 EPSIL = 0.00100000

NEWTON RAPHSON ITERATIVE TECHNIQUE CONVERGED IN 3 ITERATIONS

| BUS | BUS NAME | VOLTAGE | ANGLE | GENERATION | | LOAD | |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1.03493 | -16.01691 | 0.00000 | -0.00158 | 14.90000 | 5.00000 |
| 2 | 2 | 1.04500 | -4.98764 | 40.00001 | 46.42903 | 21.70000 | 12.70000 |
| 3 | 3 | 1.01000 | -12.74697 | 0.00000 | 25.69310 | 94.20000 | 19.00000 |
| 4 | 4 | 1.01478 | -10.27869 | -0.00001 | 0.00353 | 47.80000 | 3.90000 |
| 5 | 5 | 1.01730 | -8.74804 | 0.00005 | 0.01075 | 7.60000 | 1.60000 |
| 6 | 6 | 1.07000 | -14.21306 | 0.00002 | 11.66731 | 11.20000 | 7.50000 |
| 7 | 7 | 1.05049 | -13.33458 | -0.00007 | -0.00215 | 0.00000 | 0.00000 |
| 8 | 8 | 1.09000 | -13.33458 | 0.00000 | 18.26026 | 0.00000 | 0.00000 |
| 9 | 9 | 1.05500 | -14.91512 | 0.00005 | -0.00764 | 29.50000 | 16.60000 |
| 10 | 10 | 1.05021 | -15.07643 | 0.00001 | -0.00084 | 9.00000 | 5.80000 |
| 11 | 11 | 1.05651 | -14.77564 | -0.00001 | 0.00038 | 3.50000 | 1.80000 |
| 12 | 12 | 1.05512 | -15.06733 | -0.00000 | 0.00006 | 6.10000 | 1.60000 |
| 13 | 13 | 1.05024 | -15.14607 | 0.00000 | 0.00055 | 13.50000 | 5.80000 |
| 14 | 14 | 1.06000 | 0.00000 | 232.42153 | -15.54653 | 0.00000 | 0.00000 |

TOTAL GENERATION = 272.421650 86.501236 TOTAL LOAD = 259.000000 81.300001 TOTAL LOSSES = 13.421650 5.201235

## LIST OF OUTPUT RESULTS

DMAX = 0.00097355    EPSIL = 0.00100000

DECOUPLED ITERATIVE TECHNIQUE CONVERGED IN 15 ITERATIONS

| BUS | BUS NAME | VOLTAGE | ANGLE | GENERATION | | LOAD | |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1.03493 | -16.01573 | -0.00101 | 0.00112 | 14.90000 | 5.00000 |
| 2 | 2 | 1.04500 | -4.98766 | 39.99978 | 45.43315 | 21.70000 | 12.70000 |
| 3 | 3 | 1.01000 | -12.73702 | -0.00023 | 25.69476 | 94.20000 | 19.00000 |
| 4 | 4 | 1.01478 | -10.27868 | 0.00111 | -0.00128 | 47.80000 | 3.90000 |
| 5 | 5 | 1.01729 | -8.74803 | -0.00037 | 0.00139 | 7.60000 | 1.60000 |
| 6 | 6 | 1.07000 | -14.21327 | 0.00161 | 11.66063 | 11.20000 | 7.50000 |
| 7 | 7 | 1.05049 | -13.33451 | 0.00012 | -0.00011 | 0.00000 | 0.00000 |
| 8 | 8 | 1.09000 | -13.33451 | 0.00000 | 18.25787 | 0.00000 | 0.00000 |
| 9 | 9 | 1.05500 | -14.91502 | -0.00304 | 0.00299 | 29.50000 | 16.60000 |
| 10 | 10 | 1.05022 | -15.07639 | 0.00011 | -0.00013 | 9.00000 | 5.80000 |
| 11 | 11 | 1.05651 | -14.77572 | -0.00007 | -0.00025 | 3.50000 | 1.80000 |
| 12 | 12 | 1.05515 | -15.07356 | -0.07082 | 0.03339 | 6.10000 | 1.60000 |
| 13 | 13 | 1.05023 | -15.14305 | 0.07726 | -0.09735 | 13.50000 | 5.80000 |
| 14 | 14 | 1.06000 | 0.00000 | 232.42230 | -15.54476 | 0.00000 | 0.00000 |

TAL GENERATION = 272.421720 86.501402 TOTAL LOAD = 259.000000 81.300001 TOTAL LOSSES = 13.421719 5.201401

## LIST OF OUTPUT RESULTS

DMAX = 0.00080604 EPSIL = 0.00100000

FAST DECOUPLED ITERATIVE TECHNIQUE CONVERGED IN 10 ITERATIONS

| BUS | BUS NAME | VOLTAGE | ANGLE | GENERATION | | LOAD | |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1.03493 | -16.01756 | 0.00126 | -0.00098 | 14.90000 | 5.00000 |
| 2 | 2 | 1.04500 | -4.98765 | 40.00021 | 46.43231 | 21.70000 | 12.70000 |
| | 3 | 1.01000 | -12.74701 | 0.00024 | 25.69408 | 94.20000 | 19.00000 |
| | 4 | 1.01478 | -10.27871 | -0.00084 | 0.00104 | 47.80000 | 3.90000 |
| | 5 | 1.01729 | -8.74799 | 0.00004 | -0.00081 | 7.60000 | 1.60000 |
| 6 | 6 | 1.07000 | -14.21284 | -0.00024 | 11.66201 | 11.20000 | 7.50000 |
| 7 | 7 | 1.06049 | -13.33468 | -0.00009 | 0.00011 | 0.00000 | 0.00000 |
| 8 | 8 | 1.09000 | -13.33468 | 0.00000 | 18.25640 | 0.00000 | 0.00000 |
| 9 | 9 | 1.05500 | -14.91524 | 0.00303 | -0.00291 | 29.50000 | 16.60000 |
| 10 | 10 | 1.05022 | -15.07651 | -0.00002 | 0.00008 | 9.00000 | 5.80000 |
| 11 | 11 | 1.05651 | -14.77558 | -0.00026 | 0.00033 | 3.50000 | 1.80000 |
| 12 | 12 | 1.05517 | -15.06373 | 0.06976 | -0.08129 | 6.10000 | 1.60000 |
| 13 | 13 | 1.05022 | -15.14748 | -0.07270 | 0.08487 | 13.50000 | 5.80000 |
| 14 | 14 | 1.06000 | 0.00000 | 232.42164 | -15.54463 | 0.00000 | 0.00000 |

TOTAL GENERATION = 272.422040 86.500603 TOTAL LOAD = 259.000000 81.300001 TOTAL LOSSES = 13.422039 5.200602

L.F.STUDY(85-86-CEA),WITHOUT ADDING ANY NEW 400KV LINE

IPDATA = 0 IS-ITH = 0 IMETH = 3 ICHOIC = 0 ISTART = 0

NO. OF STUDIES = 1 PRINT OPTIONS = 2 2 2 2 2 2

LIST OF INPUT DATA

| NO. OF BUSES | NO. OF LINES | SLACK BUS | VOLT. CONT BUSES | SHUNT LOADS | MAX. ITERATIONS | CONV. LIMIT |
|---|---|---|---|---|---|---|
| 57 | 80 | 57 | 7 | 1 | 10 | .02000000 |

BUS DATA

| BUS NO. | NAME | GENERATION | | LOAD POWER | | ASSUMED BUS VOLTAGES VOLT MAG | PHASE ANGLE |
|---|---|---|---|---|---|---|---|
| 1 | | 0.0000 | 0.0000 | 3.0000 | 88.0000 | 1.0000 | 0.0000 |
| 2 | | 40.0000 | 0.0000 | 41.0000 | 21.0000 | 1.0000 | 0.0000 |
| 3 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 4 | | 0.0000 | 0.0000 | 13.0000 | 4.0000 | 1.0000 | 0.0000 |
| 5 | | 0.0000 | 0.0000 | 75.0000 | 2.0000 | 1.0000 | 0.0000 |
| 6 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 7 | | 450.0000 | 0.0000 | 150.0000 | 22.0000 | 1.0000 | 0.0000 |
| 8 | | 0.0000 | 0.0000 | 121.0000 | 26.0000 | 1.0000 | 0.0000 |
| 9 | | 0.0000 | 0.0000 | 5.0000 | 2.0000 | 1.0000 | 0.0000 |
| 10 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 11 | | 310.0000 | 0.0000 | 377.0000 | 24.0000 | 1.0000 | 0.0000 |
| 12 | | 0.0000 | 0.0000 | 18.0000 | 2.3000 | 1.0000 | 0.0000 |
| 13 | | 0.0000 | 0.0000 | 10.5000 | 5.3000 | 1.0000 | 0.0000 |
| 14 | | 0.0000 | 0.0000 | 22.0000 | 5.0000 | 1.0000 | 0.0000 |
| 15 | | 0.0000 | 0.0000 | 43.0000 | 3.0000 | 1.0000 | 0.0000 |
| 16 | | 0.0000 | 0.0000 | 42.0000 | 8.0000 | 1.0000 | 0.0000 |
| 17 | | 0.0000 | 0.0000 | 27.2000 | 9.8000 | 1.0000 | 0.0000 |
| 18 | | 0.0000 | 0.0000 | 3.3000 | 0.6000 | 1.0000 | 0.0000 |
| 19 | | 0.0000 | 0.0000 | 2.3000 | 1.0000 | 1.0000 | 0.0000 |
| 20 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 21 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 22 | | 0.0000 | 0.0000 | 6.3000 | 2.1000 | 1.0000 | 0.0000 |
| 23 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 24 | | 0.0000 | 0.0000 | 6.3000 | 3.2000 | 1.0000 | 0.0000 |
| 25 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 26 | | 0.0000 | 0.0000 | 9.3000 | 0.5000 | 1.0000 | 0.0000 |
| 27 | | 0.0000 | 0.0000 | 4.6000 | 2.3000 | 1.0000 | 0.0000 |
| 28 | | 0.0000 | 0.0000 | 17.0000 | 2.6000 | 1.0000 | 0.0000 |
| 29 | | 0.0000 | 0.0000 | 3.6000 | 1.8000 | 1.0000 | 0.0000 |
| 30 | | 0.0000 | 0.0000 | 5.8000 | 2.9000 | 1.0000 | 0.0000 |
| 31 | | 0.0000 | 0.0000 | 1.6000 | 0.8000 | 1.0000 | 0.0000 |
| 32 | | 0.0000 | 0.0000 | 3.8000 | 1.9000 | 1.0000 | 0.0000 |
| 33 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 34 | | 0.0000 | 0.0000 | 6.0000 | 3.0000 | 1.0000 | 0.0000 |
| 35 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 36 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 37 | 0.0000 | 0.0000 | 14.0000 | 7.0000 | 1.0000 | 0.0000 |
| 38 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 39 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 40 | 0.0000 | 0.0000 | 6.3000 | 3.0000 | 1.0000 | 0.0000 |
| 41 | 0.0000 | 0.0000 | 7.1000 | 4.0000 | 1.0000 | 0.0000 |
| 42 | 0.0000 | 0.0000 | 2.0000 | 1.0000 | 1.0000 | 0.0000 |
| 43 | 0.0000 | 0.0000 | 12.0000 | 1.8000 | 1.0000 | 0.0000 |
| 44 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 45 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 46 | 0.0000 | 0.0000 | 29.7000 | 11.6000 | 1.0000 | 0.0000 |
| 47 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 48 | 0.0000 | 0.0000 | 18.0000 | 8.5000 | 1.0000 | 0.0000 |
| 49 | 0.0000 | 0.0000 | 21.0000 | 10.5000 | 1.0000 | 0.0000 |
| 50 | 0.0000 | 0.0000 | 18.0000 | 5.3000 | 1.0000 | 0.0000 |
| 51 | 0.0000 | 0.0000 | 4.9000 | 2.2000 | 1.0000 | 0.0000 |
| 52 | 0.0000 | 0.0000 | 20.0000 | 10.0000 | 1.0000 | 0.0000 |
| 53 | 0.0000 | 0.0000 | 4.1000 | 1.4000 | 1.0000 | 0.0000 |
| 54 | 0.0000 | 0.0000 | 6.8000 | 3.4000 | 1.0000 | 0.0000 |
| 55 | 0.0000 | 0.0000 | 7.6000 | 2.2000 | 1.0000 | 0.0000 |
| 56 | 0.0000 | 0.0000 | 6.7000 | 2.0000 | 1.0000 | 0.0000 |
| 57 | 0.0000 | 0.0000 | 55.0000 | 17.0000 | 1.0000 | 0.0000 |

LINE DATA

| LINE NUMBER | FROM BUS | TO BUS | LINE IMPEDENCE | | HALF LINE CHARG ADMIT | | OFF NOM TR TURNS RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 57 | 1 | 0.00830 | 0.02800 | 0.00000 | 0.06450 | 1.00000 |
| 2 | 1 | 2 | 0.02980 | 0.08500 | 0.00000 | 0.04090 | 1.00000 |
| 3 | 2 | 3 | 0.01120 | 0.03660 | 0.00000 | 0.01900 | 1.00000 |
| 4 | 3 | 4 | 0.06250 | 0.13200 | 0.00000 | 0.01290 | 1.00000 |
| 5 | 3 | 5 | 0.04300 | 0.14800 | 0.00000 | 0.01740 | 1.00000 |
| 6 | 5 | 6 | 0.02000 | 0.10200 | 0.00000 | 0.01380 | 1.00000 |
| 7 | 5 | 7 | 0.03390 | 0.17300 | 0.00000 | 0.02350 | 1.00000 |
| 8 | [illegible] | 8 | 0.00990 | 0.05050 | 0.00000 | 0.02740 | 1.00000 |
| 9 | 6 | 9 | 0.03690 | 0.16970 | 0.00000 | 0.02200 | 1.00000 |
| 10 | 6 | 10 | 0.02580 | 0.08480 | 0.00000 | 0.01090 | 1.00000 |
| 11 | 8 | 11 | 0.06480 | 0.29500 | 0.00000 | 0.03860 | 1.00000 |
| 12 | 8 | 12 | 0.04810 | 0.15800 | 0.00000 | 0.02030 | 1.00000 |
| 13 | 12 | 13 | 0.01320 | 0.04340 | 0.00000 | 0.00550 | 1.00000 |
| 14 | 12 | 14 | 0.02690 | 0.08690 | 0.00000 | 0.01150 | 1.00000 |
| 15 | 57 | 14 | 0.01780 | 0.09100 | 0.00000 | 0.04940 | 1.00000 |
| 16 | 57 | 15 | 0.04540 | 0.20600 | 0.00000 | 0.02730 | .00000 |
| 17 | 57 | 16 | 0.02380 | 0.10800 | 0.00000 | 0.01430 | 1.00000 |
| 18 | 2 | 14 | 0.01670 | 0.05300 | 0.00000 | 0.02720 | 1.00000 |
| 19 | 3 | 17 | 0.00000 | 0.55500 | 0.00000 | 0.00000 | 0.97000 |
| 20 | 3 | 17 | 0.00000 | 0.43000 | 0.00000 | 0.00000 | 0.97800 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 21 | 8 | 6 | 0.03020 | 0.08410 | 0.00000 | 0.03620 | 1.00000 |
| 22 | 5 | 7 | 0.01390 | 0.07120 | 0.00000 | 0.00970 | 1.00000 |
| 23 | 9 | 11 | 0.02770 | 0.12620 | 0.00000 | 0.01640 | 1.00000 |
| 24 | 10 | 12 | 0.02230 | 0.07320 | 0.00000 | 0.00940 | 1.00000 |
| 25 | 11 | 12 | 0.01780 | 0.05900 | 0.00000 | 0.03040 | 1.00000 |
| 26 | 11 | 15 | 0.01800 | 0.08130 | 0.00000 | 0.01080 | 1.00000 |
| 27 | 11 | 16 | 0.03970 | 0.17900 | 0.00000 | 0.02380 | 1.00000 |
| 28 | 13 | 14 | 0.01710 | 0.05470 | 0.00000 | 0.00740 | 1.00000 |
| 29 | 17 | 18 | 0.45100 | 0.68500 | 0.00000 | 0.00000 | 1.00000 |
| 30 | 18 | 19 | 0.28300 | 0.43400 | 0.00000 | 0.00000 | 1.00000 |
| 31 | 19 | 20 | 0.00000 | 0.77670 | 0.00000 | 0.00000 | 1.04300 |
| 32 | 20 | 21 | 0.07360 | 0.11700 | 0.00000 | 0.00000 | 1.00000 |
| 33 | 21 | 22 | 0.00990 | 0.01520 | 0.00000 | 0.00000 | 1.00000 |
| 34 | 22 | 23 | 0.16600 | 0.25600 | 0.00000 | 0.00420 | 1.00000 |
| 35 | 23 | 24 | 0.00000 | 1.18200 | 0.00000 | 0.00000 | 1.00000 |
| 36 | 23 | 24 | 0.00000 | 1.23000 | 0.00000 | 0.00000 | 1.00000 |
| 37 | 23 | 25 | 0.00000 | 0.04730 | 0.00000 | 0.00000 | 1.04300 |
| 38 | 25 | 26 | 0.16500 | 0.25400 | 0.00000 | 0.00000 | 1.00000 |
| 39 | 26 | 27 | 0.06180 | 0.09540 | 0.00000 | 0.00000 | 1.00000 |
| 40 | 27 | 28 | 0.04180 | 0.05670 | 0.00000 | 0.00000 | 1.00000 |
| 41 | 6 | 28 | 0.00000 | 0.06480 | 0.00000 | 0.00000 | 0.96700 |
| 42 | 24 | 29 | 0.13500 | 0.20200 | 0.00000 | 0.00000 | 1.00000 |
| 43 | 29 | 30 | 0.32600 | 0.49700 | 0.00000 | 0.00000 | 1.00000 |
| 44 | 30 | 31 | 0.50700 | 0.75500 | 0.00000 | 0.00000 | 1.00000 |
| 45 | 31 | 32 | 0.03920 | 0.03600 | 0.00000 | 0.00000 | 1.00000 |
| 46 | 31 | 33 | 0.00000 | 0.95300 | 0.00000 | 0.00000 | 1.00000 |
| 47 | 33 | 34 | 0.05200 | 0.07800 | 0.00000 | 0.00160 | 1.00000 |
| 48 | 34 | 35 | 0.04300 | 0.05370 | 0.00000 | 0.00080 | 1.00000 |
| 49 | 35 | 36 | 0.02900 | 0.03660 | 0.00000 | 0.00000 | 1.00000 |
| 50 | 35 | 37 | 0.06510 | 0.10090 | 0.00000 | 0.00100 | 1.00000 |
| 51 | 36 | 38 | 0.02390 | 0.03790 | 0.00000 | 0.00000 | 1.00000 |
| 52 | 45 | 39 | 0.03000 | 0.04660 | 0.00000 | 0.00000 | 1.00000 |
| 53 | 71 | 37 | 0.01920 | 0.02950 | 0.00000 | 0.00000 | 1.00000 |
| 54 | 10 | 40 | 0.00000 | 0.74900 | 0.00000 | 0.00000 | 0.95500 |
| 55 | 40 | 41 | 0.20700 | 0.35200 | 0.00000 | 0.00000 | 1.00000 |
| 56 | 40 | 42 | 0.00000 | 0.41200 | 0.00000 | 0.00000 | 1.00000 |
| 57 | 37 | 43 | 0.02890 | 0.05850 | 0.00000 | 0.00100 | 1.00000 |
| 58 | 18 | 44 | 0.00000 | 0.10420 | 0.00000 | 0.00000 | 0.95500 |
| 59 | 13 | 45 | 0.00000 | 0.07350 | 0.00000 | 0.00000 | 0.90000 |
| 60 | 45 | 46 | 0.02300 | 0.06800 | 0.00000 | 0.00160 | 1.00000 |
| 61 | 40 | 47 | 0.01820 | 0.02330 | 0.00000 | 0.00000 | 1.00000 |
| [illegible] | 47 | 48 | 0.08340 | 0.12900 | 0.00000 | 0.00240 | 1.00000 |
| [illegible] | 46 | 49 | 0.08010 | 0.12600 | 0.00000 | 0.00000 | 1.00000 |
| [illegible] | [illegible] | 50 | 0.13650 | 0.22000 | 0.00000 | 0.00000 | 1.00000 |
| [illegible] | [illegible] | [illegible] | 0.00000 | 0.07120 | 0.00000 | 0.00000 | 0.93000 |

## LIST OF OUTPUT RESULTS

DMAX = 0.00015363 EPSIL = 0.00100000

NEWTON RAPHSON ITERATIVE TECHNIQUE CONVERGED IN 4 ITERATIONS

| BUS | BUS NAME | VOLTAGE | ANGLE | GENERATION | | LOAD | |
|---|---|---|---|---|---|---|---|
| 1 | | 1.01000 | -1.18481 | -0.00001 | -0.46260 | 3.00000 | 88.00000 |
| 2 | | 0.98474 | -5.97006 | 40.00000 | -4.62074 | 41.00000 | 21.00000 |
| 3 | | 0.98173 | -7.31889 | -0.00002 | -0.00059 | 0.00000 | 0.00000 |
| 4 | | 0.97696 | -8.52467 | 0.00001 | -0.00051 | 13.00000 | 4.00000 |
| 5 | | 0.98022 | -8.65156 | 0.00008 | 0.05919 | 75.00000 | 2.00000 |
| 6 | | 0.98454 | -7.58478 | -0.00004 | 0.01536 | 0.00000 | 0.00000 |
| 7 | | 1.00500 | -4.47147 | 450.00010 | 61.48202 | 150.00000 | 22.00000 |
| 8 | | 0.98001 | -9.59266 | -0.00003 | 2.27571 | 121.00000 | 26.00000 |
| 9 | | 0.98716 | -11.47807 | -0.00002 | 0.00157 | 5.00000 | 2.00000 |
| 10 | | 0.97399 | -10.20965 | -0.00002 | -0.00084 | 0.00000 | 0.00000 |
| 11 | | 1.01500 | -10.49009 | 310.00004 | 128.95345 | 377.00000 | 24.00000 |
| 12 | | 0.97829 | -9.82199 | 0.00002 | 0.00575 | 18.00000 | 2.30000 |
| 13 | | 0.96943 | -9.37825 | -0.00001 | 0.00283 | 10.50000 | 5.30000 |
| 14 | | 0.98785 | -7.19780 | 0.00000 | 0.00336 | 22.00000 | 5.00000 |
| 15 | | 1.01336 | -8.87245 | 0.00000 | 0.00227 | 43.00000 | 3.00000 |
| 16 | | 1.01744 | -5.40293 | 0.00001 | 0.00334 | 42.00000 | 8.00000 |
| 17 | | 1.01103 | -11.50990 | 0.00004 | -0.00159 | 27.20000 | 9.80000 |
| 18 | | 1.00844 | -13.36147 | -0.00000 | 0.00043 | 3.30000 | 0.60000 |
| 19 | | 1.01932 | -13.81090 | 0.00001 | -0.00065 | 2.30000 | 1.00000 |
| 20 | | 1.00817 | -12.83133 | -0.00001 | 0.00037 | 0.00000 | 0.00000 |
| 21 | | 1.01417 | -12.84601 | 0.00006 | 0.00048 | 0.00000 | 0.00000 |
| 22 | | 1.01258 | -12.90917 | 0.00007 | 0.00005 | 6.30000 | 2.10000 |
| 23 | | 1.00057 | -13.23379 | -0.00024 | -0.00673 | 0.00000 | 0.00000 |
| 24 | | 0.98029 | -18.71654 | 0.00011 | -0.00973 | 6.30000 | 3.20000 |
| 25 | | 0.96167 | -12.92784 | 0.00004 | 0.00232 | 0.00000 | 0.00000 |
| 26 | | 0.98378 | -11.47373 | -0.00010 | -0.00262 | 9.30000 | 0.50000 |
| 27 | | 0.99866 | -10.44832 | -0.00003 | 0.00451 | 4.60000 | 2.30000 |
| 28 | | 1.01204 | -9.74209 | 0.00033 | -0.00886 | 17.00000 | 2.60000 |
| 29 | | 0.95894 | -18.75776 | 0.00003 | -0.00033 | 3.60000 | 1.80000 |
| 30 | | 0.92865 | -19.40950 | 0.00005 | 0.00068 | 5.80000 | 2.90000 |
| 31 | | 0.93759 | -18.48443 | 0.00009 | -0.00278 | 1.60000 | 0.60000 |
| 32 | | 0.93526 | -18.52516 | 0.00002 | 0.00039 | 3.80000 | 1.90000 |
| 33 | | 0.96703 | -14.13720 | -0.00009 | -0.00437 | 0.00000 | 0.00000 |
| 34 | | 0.97343 | -13.89345 | 0.00002 | -0.00018 | 6.00000 | 3.00000 |
| 35 | | 0.98257 | -13.62037 | 0.00000 | 0.00045 | 0.00000 | 0.00000 |
| 36 | | 0.99139 | -13.43294 | 0.00004 | 0.00035 | 0.00000 | 0.00000 |
| 37 | | 1.01877 | -12.72915 | -0.00002 | 0.00128 | 14.00000 | 7.00000 |
| 38 | | 0.98931 | -13.47789 | -0.00004 | 0.00036 | 0.00000 | 0.00000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 39 | 0.97944 | -13.64110 | -0.00001 | 0.00025 | 0.00000 | 0.00000 |
| 40 | 1.00064 | -14.04908 | 0.00006 | -0.00197 | 6.80000 | 3.00000 |
| 41 | 0.97275 | -15.53702 | 0.00001 | 0.00075 | 7.40000 | 4.00000 |
| 42 | 1.01221 | -11.36190 | -0.00003 | -0.00319 | 2.00000 | 1.00000 |
| 43 | 1.02195 | -11.84846 | 0.00004 | 0.00722 | 12.00000 | 1.80000 |
| 44 | 1.03941 | -9.25738 | 0.00005 | 0.00310 | 0.00000 | 0.00000 |
| 45 | 1.07035 | -11.17237 | 0.00005 | -0.00073 | 0.00000 | 0.00000 |
| 46 | 1.04195 | -12.55068 | -0.00003 | 0.00030 | 29.70000 | 11.60000 |
| 47 | 1.03527 | -12.63575 | 0.00004 | 0.00046 | 0.00000 | 0.00000 |
| 48 | 1.04528 | -12.98777 | 0.00005 | -0.00308 | 18.00000 | 8.50000 |
| 49 | 1.03190 | -13.44176 | -0.00002 | -0.00117 | 21.00000 | 10.50000 |
| 50 | 1.05961 | -12.55091 | 0.00003 | -0.00432 | 18.00000 | 5.30000 |
| 51 | 0.98287 | -11.47205 | -0.00001 | 0.00326 | 4.90000 | 2.20000 |
| 52 | 0.97379 | -12.22924 | -0.00005 | -0.00687 | 20.00000 | 10.00000 |
| 53 | 0.99978 | -11.70240 | 0.00009 | 0.00234 | 4.10000 | 1.40000 |
| 54 | 1.03479 | -10.81064 | 0.00010 | 0.00043 | 6.80000 | 3.40000 |
| 55 | 0.97476 | -16.06116 | 0.00001 | -0.00044 | 7.60000 | 2.20000 |
| 56 | 0.97146 | -16.56956 | 0.00002 | -0.00113 | 6.70000 | 2.00000 |
| 57 | 1.04000 | 0.00000 | 478.85788 | 129.09619 | 55.00000 | 17.00000 |

TOTAL GENERATION = 1278.858800 316.784490 TOTAL LOAD = 1250.800000 336.000000 TOTAL LOSSES = 28.058731 -19.215508

## LIST OF OUTPUT RESULTS

DMAX = 0.00118210 EPSIL = 0.05000000

DECOUPLED ITERATIVE TECHNIQUE CONVERGED IN 7 ITERATIONS

| BUS | BUS NAME | VOLTAGE | ANGLE | GENERATION | | LOAD | |
|---|---|---|---|---|---|---|---|
| 1 | | 1.01000 | -1.18671 | 0.00004 | -0.76004 | 3.00000 | 58.00000 |
| 2 | | 0.98500 | -5.98209 | 39.96127 | -3.47973 | 41.00000 | 21.00000 |
| 3 | | 0.98184 | -7.32915 | -0.00089 | 0.02224 | 0.00000 | 0.00000 |
| 4 | | 0.97 | -8.52873 | 0.12587 | -0.12585 | 13.00000 | 4.00000 |
| | | 0.98000 | -8.65974 | -0.11965 | -0.28888 | 75.00000 | 2.00000 |
| | | 0.98426 | -7.59296 | 0.05934 | -0.06026 | [illegible].00000 | 0.00000 |
| | | 1.00500 | -4.48458 | 449.98062 | 62.03233 | 150.00000 | 22.00000 |
| | | 0.99000 | -9.60798 | -0.03457 | 0.41437 | 121.00000 | 26.00000 |
| | | 0.98717 | -11.49198 | 0.01648 | 0.02017 | 5.00000 | 7.00000 |
| 10 | | 0.97400 | -10.22538 | 0.04485 | 0.07313 | 0.00000 | 0.00000 |
| 11 | | 1.01500 | -10.50116 | 309.97891 | 128.94083 | 377.00000 | 24.00000 |
| 12 | | 0.97829 | -9.83467 | 0.01370 | 0.03756 | 18.00000 | 2.30000 |
| 13 | | 0.96942 | -9.39125 | -0.03770 | 0.02910 | 10.60000 | 5.30000 |
| 14 | | 0.98789 | -7.20522 | 0.10484 | -0.11909 | 22.00000 | 5.00000 |
| 15 | | 1.01337 | -8.82071 | -0.00486 | 0.02994 | 43.00000 | 3.00000 |
| 16 | | 1.01745 | -5.40742 | -0.00482 | 0.02982 | 42.00000 | 8.00000 |
| 17 | | 1.01111 | -11.52153 | -0.07257 | 0.18052 | 27.20000 | 9.80000 |
| 18 | | 1.00740 | -13.30184 | 0.04749 | -0.23038 | 3.30000 | 0.60000 |
| 19 | | 1.01843 | -13.75405 | 0.02052 | 0.03537 | 2.30000 | 1.00000 |
| 20 | | 1.00727 | -12.77770 | 0.02106 | -0.08355 | 0.00000 | 0.00000 |
| 21 | | 1.01334 | -12.79757 | 0.02496 | -0.04571 | 0.00000 | 0.00000 |
| 22 | | 1.01164 | -12.85765 | 0.09955 | -0.19494 | 6.30000 | 2.10000 |
| 23 | | 0.99814 | -13.16193 | -0.09321 | -0.40311 | 0.00000 | 0.00000 |
| 24 | | 0.97785 | -18.18733 | -0.36132 | 0.14570 | 6.30000 | 3.20000 |
| 25 | | 0.95930 | -12.85486 | 0.01472 | -0.11799 | 0.00000 | 0.00000 |
| 26 | | 0.98154 | -11.40300 | 0.00525 | -0.44812 | 9.30000 | 0.50000 |
| 27 | | 0.99692 | -10.39319 | 0.33951 | -1.80667 | 4.60[illegible] | 2.30000 |
| 28 | | 1.01150 | -9.75253 | -1.28227 | 5.11822 | 17.00000 | 2.60000 |
| 29 | | 0.95664 | -18.68350 | 0.19419 | -0.09129 | 3.50000 | 1.80000 |
| 30 | | 0.92651 | -19.29646 | 0.04032 | 0.00124 | 5.80000 | 2.90000 |
| 31 | | 0.93560 | -18.32196 | -3.40881 | 4.81658 | 1.60000 | 0.80000 |
| 32 | | 0.93284 | -18.15889 | 3.38746 | -4.81547 | 3.80000 | 1.90000 |
| 33 | | 0.96499 | -13.89255 | 0.08681 | 0.01097 | 0.00000 | 0.00000 |
| 34 | | 0.97140 | -13.6[illegible]34 | 1.10395 | -1.59369 | 6.00000 | 3.00000 |
| 35 | | 0.98094 | -13.44805 | 0.46798 | -0.40198 | 0.00000 | 0.00000 |
| 36 | | 0.99013 | -13.33055 | -1.19780 | 1.54550 | 0.00000 | 0.00000 |
| 37 | | 1.01817 | -12.68891 | 0.35124 | 0.11428 | 14.00000 | 7.00000 |
| 38 | | 0.98796 | -13.36780 | 0.12693 | -0.30876 | 0.00000 | 0.00000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 39 | 0,97771 | -13,46570 | -0,02680 | -0,16573 | 0,00000 | 0,00000 |
| 40 | 1,00061 | -14,08403 | -0,54410 | 1,04472 | 6,30000 | 3,00000 |
| 41 | 0,97140 | -15,44698 | 0,10193 | -0,18261 | 7,10000 | 4,00000 |
| 42 | 1,01222 | -11,38254 | 0,00306 | 0,00671 | 2,00000 | 1,00000 |
| 43 | 1,02145 | -11,81704 | 0,11250 | -0,25136 | 12,00000 | 1,80000 |
| 44 | 1,03931 | -9,26118 | -0,24404 | 0,32743 | 0,00000 | 0,00000 |
| 45 | 1,07028 | -11,19151 | 0,00679 | -0,03116 | 0,00000 | 0,00000 |
| 46 | 1,04183 | -12,57561 | -1,87876 | 1,96959 | 29,70000 | 11,60000 |
| 47 | 1,03500 | -12,62024 | 1,61676 | -1,43353 | 0,00000 | 0,00000 |
| 48 | 1,04524 | -13,00571 | -1,02992 | 1,21992 | 18,00000 | 8,50000 |
| 49 | 1,03176 | -13,41394 | 0,67834 | -0,59136 | 21,00000 | 10,50000 |
| 50 | 1,05962 | -12,56618 | -0,27616 | 0,21357 | 18,00000 | 5,30000 |
| 51 | 0,97756 | -11,12921 | 0,69989 | -1,95758 | 4,90000 | 2,20000 |
| 52 | 0,96733 | -11,82723 | 0,44883 | -2,48429 | 20,00000 | 10,00000 |
| 53 | 0,99614 | -11,47821 | 0,30894 | -0,53375 | 4,10000 | 1,40000 |
| 54 | 1,03457 | -10,83320 | -0,62445 | 1,75323 | 6,80000 | 3,40000 |
| 55 | 0,97252 | -15,88570 | 0,47178 | -1,24152 | 7,60000 | 2,20000 |
| 56 | 0,96982 | -16,45198 | -0,11613 | 0,30738 | 6,70000 | 2,00000 |
| 57 | 1,04000 | 0,00000 | 479,25882 | 128,98084 | 55,00000 | 17,00000 |

TOTAL GENERATION = 1278,941700 317,174700 TOTAL LOAD = 1250,800000 336,000000 TOTAL LOSSES = 28,141647 -18,825302

## LIST OF OUTPUT RESULTS

DMAX = 0.01986371 EPSIL = 0.02000000

FAST DECOUPLED ITERATIVE TECHNIQUE CONVERGED IN 6 ITERATIONS

| BUS | BUS NAME | VOLTAGE | ANGLE | GENERATION | | LOAD | |
|---|---|---|---|---|---|---|---|
| 1 | | 1.01000 | -1.18446 | 0.00167 | -0.76866 | 3.00000 | 88.00000 |
| 2 | | 0.98500 | -5.97264 | 40.00375 | -3.67385 | 41.00000 | 21.00000 |
| 3 | | 0.98185 | -7.31812 | 0.00034 | -0.00674 | 0.00000 | 0.00000 |
| 4 | | 0.97685 | -8.51885 | -0.00328 | 0.00741 | 13.00000 | 4.00000 |
| 5 | | 0.98000 | -8.64321 | 0.00345 | -0.60557 | 75.00000 | 2.00000 |
| 6 | | 0.98446 | -7.57707 | -0.01122 | -0.01568 | 0.00000 | 0.00000 |
| 7 | | 1.00500 | -4.46509 | 450.00189 | 61.74142 | 150.00000 | 22.00000 |
| 8 | | 0.98000 | -9.58682 | -0.01836 | 2.17740 | 121.00000 | 26.00000 |
| 9 | | 0.98717 | -11.47347 | -0.00064 | -0.00264 | 5.00000 | 2.00000 |
| 10 | | 0.97402 | -10.20420 | 0.01632 | -0.04342 | 0.00000 | 0.00000 |
| 11 | | 1.01500 | -10.48647 | 309.99691 | 128.88437 | 377.00000 | 24.00000 |
| 12 | | 0.97833 | -9.81855 | -0.00626 | 0.00310 | 18.00000 | 2.30000 |
| 13 | | 0.96951 | -9.37543 | 0.00440 | -0.02650 | 10.50000 | 5.30000 |
| 14 | | 0.98796 | -7.19713 | -0.01849 | 0.01748 | 22.00000 | 5.00000 |
| 15 | | 1.01336 | -8.86984 | 0.00035 | -0.00766 | 43.00000 | 3.00000 |
| 16 | | 1.01744 | -5.40153 | 0.00086 | -0.00794 | 42.00000 | 8.00000 |
| 17 | | 1.01116 | -11.50769 | 0.04616 | -0.06509 | 27.20000 | 9.80000 |
| 18 | | 1.00835 | -13.37454 | -0.04539 | 0.07089 | 3.30000 | 0.60000 |
| 19 | | 1.01922 | -13.82265 | 0.00600 | -0.00627 | 2.30000 | 1.00000 |
| 20 | | 1.00805 | -12.84395 | -0.01326 | 0.02079 | 0.00000 | 0.00000 |
| 21 | | 1.01405 | -12.85776 | -0.01924 | 0.02441 | 0.00000 | 0.00000 |
| 22 | | 1.01245 | -12.92208 | -0.07316 | 0.11416 | 6.30000 | 2.10000 |
| 23 | | 1.00029 | -13.25571 | -0.08274 | 0.10393 | 0.00000 | 0.00000 |
| 24 | | 0.98009 | -18.23131 | 0.02498 | -0.02716 | 6.30000 | 3.20000 |
| 25 | | 0.96139 | -12.94996 | -0.00527 | 0.03353 | 0.00000 | 0.00000 |
| 26 | | 0.98341 | -11.49338 | -0.09168 | 0.16650 | 9.30000 | 0.50000 |
| 27 | | 0.99833 | -10.46159 | -0.54233 | 0.72537 | 4.60000 | 2.30000 |
| 28 | | 1.01196 | -9.73343 | 1.49961 | -2.01020 | 17.00000 | 2.60000 |
| 29 | | 0.95875 | -18.77251 | 0.00079 | 0.00767 | 3.60000 | 1.80000 |
| 30 | | 0.92845 | -19.42388 | 0.02922 | -0.03303 | 5.80000 | 2.90000 |
| 31 | | 0.93722 | -18.51168 | 1.59849 | -1.55546 | 1.60000 | 0.80000 |
| 32 | | 0.93423 | -16.59008 | -1.59366 | 1.56858 | 3.80000 | 1.90000 |
| 33 | | 0.96658 | -14.17672 | 0.04520 | -0.05349 | 0.00000 | 0.00000 |
| 34 | | 0.97293 | -13.93576 | -0.39711 | 0.54307 | 6.00000 | 3.00000 |
| 35 | | 0.98221 | -13.65156 | -0.10078 | 0.10186 | 0.00000 | 0.00000 |
| 36 | | 0.99118 | -13.45345 | 0.37285 | -0.46772 | 0.00000 | 0.00000 |
| 37 | | 1.01869 | -12.73814 | 0.02471 | -0.03456 | 14.00000 | 7.00000 |
| 38 | | 0.98908 | -13.50014 | -0.08371 | 0.12076 | 0.00000 | 0.00000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 39 | 0.97906 | -13.67371 | -0.05486 | 0.06831 | 0.00000 | 0.00000 |
| 40 | 1.00072 | -14.03850 | 0.25818 | -0.37128 | 6.30000 | 3.00000 |
| 41 | 0.97256 | -15.54872 | -0.00356 | 0.01179 | 7.10000 | 4.00000 |
| 42 | 1.01226 | -11.35499 | 0.00169 | -0.00339 | 2.00000 | 1.00000 |
| 43 | 1.02191 | -11.85522 | -0.03916 | 0.06849 | 12.00000 | 1.80000 |
| 44 | 1.03948 | -9.25728 | 0.10746 | -0.15032 | 0.00000 | 0.00000 |
| 45 | 1.07044 | -11.16822 | -0.00910 | 0.01407 | 0.00000 | 0.00000 |
| 46 | 1.04206 | -12.54501 | 0.89530 | -1.10641 | 29.70000 | 11.60000 |
| 47 | 1.03523 | -12.64071 | -0.82498 | 0.96466 | 0.00000 | 0.00000 |
| 48 | 1.04533 | -12.98450 | 0.37004 | -0.52021 | 18.00000 | 8.50000 |
| 49 | 1.03184 | -13.44680 | -0.20425 | 0.30501 | 21.00000 | 10.50000 |
| 50 | 1.05963 | -12.54611 | 0.08378 | -0.12007 | 18.00000 | 5.30000 |
| 51 | 0.98160 | -11.55144 | -0.41927 | 0.53051 | 4.90000 | 2.20000 |
| 52 | 0.97222 | -12.33150 | -0.60885 | 0.93328 | 20.00000 | 10.00000 |
| 53 | 0.99873 | -11.76736 | -0.29828 | 0.37501 | 4.10000 | 1.40000 |
| 54 | 1.03476 | -10.80322 | 0.61255 | -0.77547 | 6.80000 | 3.40000 |
| 55 | 0.97431 | -16.09467 | -0.29956 | 0.45135 | 7.60000 | 2.20000 |
| 56 | 0.97116 | -16.59074 | 0.08707 | -0.10455 | 6.70000 | 2.00000 |
| 57 | 1.04000 | 0.00000 | 478.76959 | 128.98431 | 55.00000 | 17.00000 |

TOTAL GENERATION = 1278.995100 316.576160 TOTAL LOAD = 1250.800000 336.000000 TOTAL LOSSES = 28.195084 -19.423843

HYDRO POWER EVACUATION FOR APRIL 1982.

IPDATA = 0 ISMITH = 1 INETH = 3 ICHOIC = 0 ISTART = 0

NO. OF STUDIES = 1 PRINT OPTIONS = 2 2 2 2 2 2

LIST OF INPUT DATA

| NO. OF BUSES | NO. OF LINES | SLACK BUS | VOLT. CONT BUSES | SHUNT LOADS | MAX. ITERATIONS | CONV. LIMIT | BASE POWER |
|---|---|---|---|---|---|---|---|
| 100 | 128 | 1 | 19 | 37 | 10 | .00100000 | 100.00 |

BUS DATA

| BUS NO. | NAME | GENERATION | | LOAD POWER | | ASSUMED BUS VOLTAGES VOLT MAG | PHASE ANGLE |
|---|---|---|---|---|---|---|---|
| 1 | OBRA(TH)10.5 | 136.0000 | 90.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 2 | OBRA(TH)220 | 0.0000 | 0.0000 | 58.2000 | 40.0000 | 1.0000 | 0.0000 |
| 3 | OBRA A 15.75 | 398.0000 | 175.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 4 | OBRA'A'420 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 5 | PANKI 11 | 24.0000 | 20.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 6 | PANKI 132 | 0.0000 | 0.0000 | 80.0000 | 60.0000 | 1.0000 | 0.0000 |
| 7 | PANKI(EXT)11 | 140.0000 | 90.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 8 | PANKI 220 | 0.0000 | 0.0000 | 55.0000 | 34.5000 | 1.0000 | 0.0000 |
| 9 | PANKI 400 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 10 | HDJ'A' 11 | 22.0000 | 10.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 11 | HDJ 132 | 0.0000 | 0.0000 | 110.0000 | 90.0000 | 1.0000 | 0.0000 |
| 12 | HDJ'B' 11 | 50.0000 | 40.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 13 | HDJ 220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 14 | RIHAND 11 | 40.0000 | 30.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 15 | RIHAND 132 | 0.0000 | 0.0000 | 73.0000 | 58.0000 | 1.0000 | 0.0000 |
| 16 | OBRA(H) 11 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 17 | OBRA(H)132 | 0.0000 | 0.0000 | 18.0000 | 10.5000 | 1.0000 | 0.0000 |
| 18 | KHATIMA 11 | 25.0000 | 15.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 19 | KHATIMA132 | 0.0000 | 0.0000 | 9.6000 | 8.0000 | 1.0000 | 0.0000 |
| 20 | CHILLA 11 | 131.0000 | 90.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 21 | CHILLA 132 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 22 | RAMGANGA 11 | 48.0000 | 30.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 23 | RAMGANGA132 | 0.0000 | 0.0000 | 2.5000 | 1.2000 | 1.0000 | 0.0000 |
| 24 | CHIBRO 11 | 120.0000 | 55.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 25 | CHIBRO 220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 26 | DAKRANI 11 | 33.0000 | 20.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 27 | DAKRANI 132 | 0.0000 | 0.0000 | 2.5000 | 1.0000 | 1.0000 | 0.0000 |
| 28 | DHALIPUR 11 | 51.0000 | 20.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 29 | DHALIPUR132 | 0.0000 | 0.0000 | 2.5000 | 1.0000 | 1.0000 | 0.0000 |
| 30 | KULHAL 11 | 80.0000 | 50.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 31 | KULHAL 132 | 0.0000 | 0.0000 | 2.5000 | 1.0000 | 1.0000 | 0.0000 |
| 32 | ROBGANG 132 | 0.0000 | 0.0000 | 18.0000 | 13.5000 | 1.0000 | 0.0000 |
| 33 | SAHUPURI132 | 0.0000 | 0.0000 | 50.0000 | 42.0000 | 1.0000 | 0.0000 |
| 34 | SAHUPURI 220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 35 | GAJIPUR 132 | 0.0000 | 5.0000 | 12.0000 | 7.2000 | 1.0000 | 0.0000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 36 MAU 132 | 0.0000 | 0.0000 | 13.2000 | 10.0000 | 1.0000 | 0.0000 |
| 37 GKP 132 | 0.0000 | 0.0000 | 32.0000 | 35.0000 | 1.0000 | 0.0000 |
| 38 GKP 220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| [illegible] KHALBAD 132 | 0.0000 | 0.0000 | 9.6000 | 6.0000 | 1.0000 | 0.0000 |
| 40 BASTI 62 | 0.0000 | 0.0000 | 9.6000 | 6.0000 | 1.0000 | 0.0000 |
| 41 FZD 132 | 0.0000 | 0.0000 | 16.0000 | 16.0000 | 1.0000 | 0.0000 |
| 42 MANDADIH132 | 0.0000 | 0.0000 | 22.0000 | 20.0000 | 1.0000 | 0.0000 |
| 43 JAUNPUR 152 | 0.0000 | 0.0000 | 15.0000 | 12.0000 | 1.0000 | 0.0000 |
| 44 MIRZAPUR152 | 0.0000 | 0.0000 | 8.0000 | 5.0000 | 1.0000 | 0.0000 |
| 45 JIGNA 132 | 0.0000 | 0.0000 | 8.0000 | 6.0000 | 1.0000 | 0.0000 |
| 46 SLN 132 | 0.0000 | 0.0000 | 58.0000 | 50.5800 | 1.0000 | 0.0000 |
| 47 SLN 220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 48 SLN'A' 400 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 49 ALLD 132 | 0.0000 | 0.0000 | 34.0000 | 34.0000 | 1.0000 | 0.0000 |
| 50 ALLD 220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 51 LUCKNOW132 | 0.0000 | 0.0000 | 50.0000 | 31.0000 | 1.0000 | 0.0000 |
| 52 LUCKNOW220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 53 LUCKNOW400 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 54 SITAPUR182 | 0.0000 | 0.0000 | 28.0000 | 18.0000 | 1.0000 | 0.0000 |
| 55 SITAPUR220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 56 SHAJPUR132 | 0.0000 | 0.0000 | 22.0000 | 13.5000 | 1.0000 | 0.0000 |
| 57 SHAHPUR220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 58 DHUNA 132 | 0.0000 | 0.0000 | 32.0000 | 31.0000 | 1.0000 | 0.0000 |
| 59 KHURJA 132 | 0.0000 | 0.0000 | 20.0000 | 17.0000 | 1.0000 | 0.0000 |
| 60 KHURJA 220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 61 BHOOR 132 | 0.0000 | 0.0000 | 0.0000 | 25.0000 | 1.0000 | 0.0000 |
| 62 MURAD 132 | 0.0000 | 0.0000 | 60.0000 | 48.0000 | 1.0000 | 0.0000 |
| 63 MURAD 220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 64 MURAD 400 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 65 MEERUT132 | 0.0000 | 0.0000 | 40.0000 | 40.0000 | 1.0000 | 0.0000 |
| 66 MEERUT220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0[illegible]0 | 0.0000 |
| 67 SHAMLI220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 68 SAHAPUR132 | 0.0000 | 0.0000 | 18.0000 | 18.0000 | 1.0000 | 0.0000 |
| 69 SAHAPUR220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 70 ROORKEE 52 | 0.0000 | 0.0000 | 6.0000 | 5.0000 | 1.0000 | 0.0000 |
| 71 HARDWAR132 | 0.0000 | 0.0000 | 18.0000 | 16.0000 | 1.0000 | 0.0000 |
| 72 RISH 132 | 0.0000 | 0.0000 | 22.0000 | 17.0000 | 1.0000 | 0.0000 |
| 73 RISH 220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 74 DDN 132 | 0.0000 | 0.0000 | 13.0000 | 10.0000 | 1.0000 | 0.0000 |
| 75 KHODRI 132 | 0.0000 | 0.0000 | 2.5000 | 1.0000 | 1.0000 | 0.0000 |
| 76 KHODRI 220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 77 NEHTAUR132 | 0.0000 | 0.0000 | 20.0000 | 24.0000 | 1.0000 | 0.0000 |
| 78 KASHPUR132 | 0.0000 | 0.0000 | 5.0000 | 3.0000 | 1.0000 | 0.0000 |
| 79 MBD 132 | 0.0000 | 0.0000 | 36.0000 | 36.0000 | 1.0000 | 0.0000 |
| 80 MBD 220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 81 GAJRALA 72 | 0.0000 | 0.0000 | 9.0000 | 7.0000 | 1.0000 | 0.0000 |
| 82 HAPUR 132 | 0.0000 | 0.0000 | 18.0000 | 18.0000 | 1.0000 | 0.0000 |
| 83 SHAGANJ132 | 0.0000 | 0.0000 | 5.0000 | 4.0000 | 1.0000 | 0.0000 |
| 84 HALDWANI132 | 0.0000 | 0.0000 | 8.0000 | 6.0000 | 1.0000 | 0.0000 |
| 85 MAINPURI220 | 0.0000 | 0.0000 | 55.0000 | 48.0000 | 1.0000 | 0.0000 |
| 86 MUZAFFR220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 87 MUZAFFR132 | 0.0000 | 0.0000 | 32.0000 | 30.0000 | 1.0000 | 0.0000 |
| 88 AZAM220 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 89 AZAM132 | 0.0000 | 0.0000 | 10.0000 | 7.5000 | 1.0000 | 0.0000 |
| 90 SHAMLI132 | 0.0000 | 0.0000 | 15.0000 | 12.0000 | 1.0000 | 0.0000 |
| 91 OBRA'B'15.75 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 92 OBRA'B'420 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 93 SLN'B' 400 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 94 OBRA'A' 33 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 95 OBRA'B' 33 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 96 SLN 'A' 33 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 97 SLN 'B' 33 | 0.0000 | 0. 000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 98 PANKI 33 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 99 LKO 33 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 100 MURAD 33 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |

LINE DATA

| LINE NUMBER | FROM BUS | TO BUS | LINE IMPEDENCE | | HALF LINE CHARG ADMIT | | OFF NOM TR TURNS RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 4 OBRA'A'420 | 9 PANKI 400 | 0.00790 | 0.08120 | 0.00000 | 0.26500 | 1.00000 |
| 2 | 9 PANKI 400 | 64 MURAD 400 | 0.00796 | 0.08112 | 0.00000 | 0.25500 | 1.00000 |
| 3 | 48 SLN'A' 400 | 53 LUCKNOW400 | 0.00298 | 0.03009 | 0.00000 | 0.09820 | 1.00000 |
| 4 | 48 SLN'A' 400 | 4 OBRA'A'420 | 0.00496 | 0.04775 | 0.00000 | 0.06013 | 1.00000 |
| 5 | 63 MURAD 220 | 64 MURAD 400 | 0.00000 | 0.02604 | 0.00000 | 0.00000 | 1.02500 |
| 6 | 2 OBRA(TH)220 | 34 SAHUPURI 220 | 0.00811 | 0.03877 | 0.00000 | 0.13220 | 1.00000 |
| 7 | 2 OBRA(TH)220 | 50 ALLD 220 | 0.01000 | 0.02370 | 0.00000 | 0.07200 | 1.00000 |
| 8 | 38 GKP 220 | 47 SLN 220 | 0.02470 | 0.10685 | 0.00000 | 0.10120 | 1.00000 |
| 9 | 50 ALLD 220 | 8 PANKI 220 | 0.01722 | 0.08229 | 0.00000 | 0.28059 | 1.00000 |
| 10 | 8 PANKI 220 | 52 LUCKNOW220 | 0.00505 | 0.02413 | 0.00000 | 0.08229 | 1.00000 |
| 11 | 8 PANKI 220 | 85 MAINPURI220 | 0.01292 | 0.06171 | 0.00000 | 0.21043 | 1.00000 |
| 12 | 85 MAINPURI220 | 13 HDJ 220 | 0.01060 | 0.05064 | 0.00000 | 0.17265 | 1.00000 |
| 13 | 60 KHURJA 220 | 63 MURAD 220 | 0.00497 | 0.02374 | 0.00000 | 0.08093 | 1.00000 |
| 14 | 13 HDJ 220 | 60 KHURJA 220 | 0.00373 | 0.01780 | 0.00000 | 0.06870 | 1.00000 |
| 15 | 63 MURAD 220 | 67 SHAMLI220 | 0.01739 | 0.08307 | 0.00000 | 0.07932 | 1.00000 |
| 16 | 13 HDJ 220 | 80 MBD 220 | 0.01845 | 0.09395 | 0.00000 | 0.07400 | 1.00000 |
| 17 | 73 RISH 220 | 86 MUZAFFR220 | 0.01390 | 0.06997 | 0.00000 | 0.05690 | 1.00000 |
| 18 | 63 MURAD 220 | 66 MEERUT220 | 0.00761 | 0.03832 | 0.00000 | 0.03120 | 1.00000 |
| 19 | 69 SAHAPUR220 | 67 SHAMLI220 | 0.01150 | 0.05790 | 0.00000 | 0.04711 | 1.00000 |
| 20 | 69 SAHAPUR220 | 76 KHODRI 220 | 0.00720 | 0.03442 | 0.00000 | 0.11720 | 1.00000 |
| 21 | 66 MEERUT220 | 86 MUZAFFR220 | 0.00993 | 0.04998 | 0.00000 | 0.04067 | 1.00000 |
| 22 | 73 RISH 220 | 76 KHODRI 220 | 0.01440 | 0.07247 | 0.00000 | 0.05898 | 1.00000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23 | 76 KHODRI 220 | 25 CHIPRO 220 | 0.00021 | 0.00099 | 0.00000 | 0.00337 | 1.00000 |
| 24 | 52 LUCKNOW220 | 55 SITAPUR220 | 0.01589 | 0.07997 | 0.00000 | 0.06508 | 1.00000 |
| 25 | 2 OBRA(TH)220 | 17 OBRA(H)132 | 0.00056 | 0.04133 | 0.00000 | 0.00061 | 1.00000 |
| 26 | 17 OBRA(H)132 | 15 RIHAND 132 | 0.01582 | 0.03767 | 0.00000 | 0.01735 | 1.00000 |
| 27 | 15 RIHAND 132 | 32 ROBGANG 132 | 0.0260- | 0.06205 | 0.00000 | 0.02849 | 1.00000 |
| 28 | 17 OBRA(H)132 | 32 ROBGANG 132 | 0.01303 | 0.03102 | 0.00000 | 0.01429 | 1.00000 |
| 29 | 32 ROBGANG 132 | 33 SAHUPURI132 | 0.04048 | 0.09640 | 0.00000 | 0.04439 | 1.00000 |
| 30 | 32 ROBGANG 132 | 44 MIRZAPUR152 | 0.04680 | 0.11760 | 0.00000 | 0.04860 | 1.00000 |
| 31 | 33 SAHUPURI132 | 35 GAJIPUR 132 | 0.05100 | 0.13100 | 0.00000 | 0.01220 | 1.00000 |
| 32 | 33 SAHUPURI132 | 36 MAU 132 | 0.09120 | 0.21717 | 0.00000 | 0.02500 | 1.00000 |
| 33 | 33 SAHUPURI132 | 42 MANDADIH132 | 0.05000 | 0.12500 | 0.00000 | 0.05200 | 1.000. |
| 34 | 35 GAJIPUR 132 | 36 MAU 132 | 0.04080 | 0.10480 | 0.00000 | 0.00980 | 1.00000 |
| 35 | 37 GKP 132 | 36 MAU 132 | 0.04932 | 0.11745 | 0.00000 | 0.05408 | 1.00000 |
| 36 | 37 GKP 132 | 39 KHALBAD 132 | 0.03400 | 0.08750 | 0.00000 | 0.00900 | 1.00000 |
| 37 | 39 KHALBAD 132 | 40 BASTI 62 | 0.02550 | 0.06550 | 0.00000 | 0.00620 | 1.00000 |
| 38 | 41 FZD 132 | 46 SLN 132 | 0.05491 | 0.13022 | 0.00000 | 0.01420 | 1.00000 |
| 39 | 42 MANDADIH132 | 43 JAUNPUR 152 | 0.05000 | 0.13500 | 0.00000 | 0.01380 | 1.00000 |
| 40 | 44 MIRZAPUR152 | 45 JIGNA 132 | 0.01700 | 0.03950 | 0.00000 | 0.01800 | 1.00000 |
| 41 | 51 LUCKNOW132 | 54 SITAPUR182 | 0.08004 | 0.20147 | 0.00000 | 0.02072 | 1.00000 |
| 42 | 54 SITAPUR182 | 56 SHAJPUR132 | 0.08560 | 0.21550 | 0.00000 | 0.02216 | 1.00000 |
| 43 | 56 SHAJPUR132 | 58 DHONA 132 | 0.03816 | 0.09086 | 0.00000 | 0.04184 | 1.00000 |
| 44 | 58 DHONA 132 | 19 KHATIMA132 | 0.03908 | 0.09307 | 0.00000 | 0.04286 | 1.00000 |
| 45 | 2 OBRA(TH)220 | 15 RIHAND 132 | 0.03258 | 0.18200 | 0.00000 | 0.00843 | 1.00000 |
| 46 | 59 KHURJA 132 | 61 BHOOR 132 | 0.01945 | 0.04955 | 0.00000 | 0.00500 | 1.00000 |
| 47 | 61 BHOOR 132 | 62 MURAD 132 | 0.05100 | 0.13600 | 0.00000 | 0.01390 | 1.00000 |
| 48 | 70 ROORKEE 52 | 68 SAHAPUR132 | 0.01442 | 0.03435 | 0.00000 | 0.01582 | 1.00000 |
| 49 | 70 ROORKEE 52 | 71 HARDWAR132 | 0.01580 | 0.03767 | 0.00000 | 0.01735 | 1.00000 |
| 50 | 77 NEHTAUR132 | 70 ROORKEE 52 | 0.04048 | 0.09640 | 0.00000 | 0.04439 | 1.00000 |
| 51 | 71 HARDWAR132 | 72 RISH 132 | 0.02233 | 0.05318 | 0.00000 | 0.00612 | 1.00000 |
| 52 | 74 DDN 132 | 31 KULHAL 132 | 0.04860 | 0.10000 | 0..J000 | 0.00900 | 1.00000 |
| 53 | 72 RISH 132 | 74 DDN 132 | 0.01861 | 0.04432 | 0.00000 | 0.02040 | 1.00000 |
| 54 | 74 DDN 132 | 29 DHALIPUR132 | 0.03860 | 0.09880 | 0.00000 | 0.00900 | 1.00000 |
| 55 | 31 KULHAL 132 | 29 DHALIPUR132 | 0.00450 | 0.01100 | 0.00000 | 0.00120 | 1.00000 |
| 56 | 29 DHALIPUR132 | 27 DAKRANI 132 | 0.00450 | 0.01100 | 0.00000 | 0.00120 | 1.00000 |
| 57 | 27 DAKRANI 132 | 75 KHODRI 132 | 0.00450 | 0.01100 | 0.00000 | 0.00120 | 1.00000 |
| 58 | 77 NEHTAUR132 | 23 RAMGANGA132 | 0.02699 | 0.06426 | 0.00000 | 0.02960 | 1.00000 |
| 59 | 79 MBD 132 | 77 NEHTAUR132 | 0.01603 | 0.03878 | 0.00000 | 0.07000 | 1.00000 |
| 60 | 23 RAMGANGA132 | 78 KASHPUR132 | 0.02280 | 0.05430 | 0.00000 | 0.02500 | 1.00000 |
| 61 | 79 MBD 132 | 81 GAJRALA 72 | 0.04600 | 0.11530 | 0.00000 | 0.01220 | 1.00000 |
| 62 | 78 KASHPUR132 | 79 MBD 132 | 0.05677 | 0.14300 | 0.00000 | 0.01470 | 1.00000 |
| 63 | 81 GAJRALA 72 | 82 HAPUR 132 | 0.04700 | 0.11650 | 0.00000 | 0.01340 | 1.00000 |
| 64 | 11 HOJ 132 | 59 KHURJA 132 | 0.04188 | 0.10542 | 0.00000 | 0.01084 | 1.00000 |
| 65 | 43 JAUNPUR 152 | 83 SHAGANJ132 | 0.04010 | 0.10075 | 0.00000 | 0.01040 | 1.00000 |
| 66 | 84 HALDWANI132 | 78 KASHPUR132 | 0.05398 | 0.13588 | 0.00000 | 0.01397 | 1.00000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 67 | 21 CHILLA 132 | 72 RISH 132 | 0.01396 | 0.03514 | 0.00000 | 0.00361 | 1.00000 |
| 68 | 7 HARDWAR132 | 21 CHILLA 132 | 0.00331 | 0.02216 | 0.00000 | 0.00250 | 1.00000 |
| 69 | 77 NEHTAUR132 | 21 CHILLA 132 | 0.08097 | 0.20382 | 0.00000 | 0.02096 | 1.00000 |
| 70 | 58 DHORA 132 | 79 MBD 132 | 0.04141 | 0.09861 | 0.00000 | 0.04541 | 1.00000 |
| 71 | 14 KIHAND 11 | 15 KIHAND 132 | 0.00000 | 0.03400 | 0.00000 | 0.00000 | 0.95000 |
| 72 | 16 OBRA(H) 11 | 17 OBRA(H)132 | 0.00000 | 0.16650 | 0.00000 | 0.00000 | 0.95000 |
| 73 | 1 OBRA(TH)10.5 | 2 OBRA(TH)220 | 0.00000 | 0.02430 | 0.00000 | 0.00000 | 0.95000 |
| 74 | 3 OBRA A 15.75 | 4 OBRA'A'420 | 0.00000 | 0.02010 | 0.00000 | 0.00000 | 1.00000 |
| 75 | 2 OBRA(TH)220 | 4 OBRA'A'420 | 0.00000 | 0.02508 | 0.00000 | 0.00000 | 1.05000 |
| 76 | 18 KHATIMA 11 | 19 KHATIMA132 | 0.00000 | 0.29550 | 0.00000 | 0.00000 | 1.00000 |
| 77 | 7 PANKI(EXT)11 | 8 PANKI 220 | 0.00000 | 0.07971 | 0.00000 | 0.00000 | 1.00000 |
| 78 | 6 PANKI 132 | 8 PANKI 220 | 0.00000 | 0.05000 | 0.00000 | 0.00000 | 1.00000 |
| 79 | 8 PANKI 220 | 9 PANKI 400 | 0.00000 | 0.05208 | 0.00000 | 0.00000 | 1.00000 |
| 80 | 5 PANKI 11 | 6 PANKI 132 | 0.00000 | 0.27500 | 0.00000 | 0.00000 | 1.00000 |
| 81 | 10 HDJ'A' 11 | 11 HDJ 132 | 0.00000 | 0.14625 | 0.00000 | 0.00000 | 0.95000 |
| 82 | 12 HDJ'B' 11 | 13 HDJ 220 | 0.00000 | 0.05225 | 0.00000 | 0.00000 | 0.95000 |
| 83 | 11 HDJ 132 | 13 HDJ 220 | 0.00000 | 0.03884 | 0.00000 | 0.00000 | 1.00000 |
| 84 | 30 KULHAL 11 | 31 KULHAL 132 | 0.00000 | 0.30000 | 0.00000 | 0.00000 | 1.00000 |
| 85 | 28 DHALIPUR 11 | 29 DHALIPUR132 | 0.00000 | 0.30000 | 0.00000 | 0.00000 | 1.00000 |
| 86 | 26 DAKRANI 11 | 27 DAKRANI 132 | 0.00000 | 0.50000 | 0.00000 | 0.00000 | 1.00000 |
| 87 | 24 CHIBRO 11 | 25 CHIBRO 220 | 0.00000 | 0.09420 | 0.00000 | 0.00000 | 1.00000 |
| 88 | 22 RAMGANGA 11 | 23 RAMGANGA132 | 0.00000 | 0.07500 | 0.00000 | 0.00000 | 0.95000 |
| 89 | 20 CHILLA 11 | 21 CHILLA 132 | 0.00000 | 0.[illegible]6500 | 0.00000 | 0.00000 | 0.95000 |
| 90 | 33 SAHUPUR1132 | 34 SAHUPURI 220 | 0.00000 | 0.04660 | 0.00000 | 0.00000 | 1.00000 |
| 91 | 37 GKP 132 | 38 GKP 220 | 0.00000 | 0.05000 | 0.00000 | 0.00000 | 1.00000 |
| 92 | 46 SLN 132 | 47 SLN 220 | 0.00000 | 0.05000 | 0.00000 | 0.00000 | 1.00000 |
| 93 | 47 SLN 220 | 48 SLN'A' 400 | 0.00000 | 0.05206 | 0.00000 | 0.00000 | 1.07500 |
| 94 | 49 ALLD 132 | 50 ALLD 220 | 0.00000 | 0.08000 | 0.00000 | 0.00000 | 1.05000 |
| 95 | 51 LUCKNOW132 | 52 LUCKNOW220 | 0.00000 | 0.04900 | 0.00000 | 0.00000 | 1.00000 |
| 96 | 52 LUCKNOW220 | 53 LUCKNOW400 | 0.00000 | 0.06000 | 0.00000 | 0.00000 | 0.95000 |
| 97 | 59 KHURJA 132 | 60 KHURJA 220 | 0.[illegible]0000 | 0.10000 | 0.00000 | 0.00000 | 1.02500 |
| 98 | 62 MURAD 132 | 63 MURAD 220 | 0.00000 | 0.05000 | 0.00000 | 0.00000 | 1.05000 |
| 99 | 65 MEERUT132 | 66 MEERUT220 | 0.00000 | 0.04640 | 0.00000 | 0.00000 | 1.00000 |
| 100 | 68 SAHAPUR132 | 69 SAHAPUR220 | 0.00000 | 0.05088 | 0.00000 | 0.00000 | 1.05000 |
| 101 | 72 RISH 132 | 73 RISH 220 | 0.00000 | 0.10320 | 0.00000 | 0.00000 | 0.98000 |
| 102 | 75 KHODRI 132 | 76 KHODRI 220 | 0.00000 | 0.10000 | 0.00000 | 0.00000 | 1.00000 |
| 103 | 79 MBD 132 | 80 MBD 220 | 0.00000 | 0.05000 | 0.00000 | 0.00000 | 1.05000 |
| 104 | 54 SITAPUR182 | 55 SITAPUR220 | 0.00000 | 0.10000 | 0.00000 | 0.00000 | 1.00000 |
| 105 | 56 SHAJPUR132 | 57 SHAHPUR220 | 0.00000 | 0.10000 | 0.00000 | 0.00000 | 1.00000 |
| 106 | 89 AZAM132 | 88 AZAM220 | 0.00000 | 0.10000 | 0.00000 | 0.00000 | 1.00000 |
| 107 | 90 SHAMLI132 | 67 SHAMLI220 | 0.00000 | 0.05000 | 0.00000 | 0.00000 | 1.00000 |
| 108 | 87 MUZAFFR132 | 86 MUZAFFR220 | 0.00000 | 0.05000 | 0.00000 | 0.00000 | 1.00000 |
| 109 | 34 SAHUPURI 220 | 88 AZAM220 | 0.01738 | 0.08747 | 0.00000 | 0.07117 | 1.00000 |
| 110 | 89 AZAM132 | 36 MAU 132 | 0.02547 | 0.04875 | 0.00000 | 0.02245 | 0.95000 |
| 111 | 90 SHAMLI132 | 87 MUZAFFR132 | 0.04561 | 0.11479 | 0.00000 | 0.01181 | 1.00000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 112 | 91 OBRA'B'15.75 | 92 OBRA'B'420 | 0.00000 | 0.02915 | 0.00000 | 0.00000 | 1.00000 |
| 113 | 2 OBRA(TH)220 | 92 OBRA'B'420 | 0.00000 | 0.05208 | 0.00000 | 0.00000 | 1.05000 |
| 114 | 47 SLN 20 | 93 SLN'B' 400 | 0.00000 | 0.05208 | 0.00000 | 0.00000 | 1.07500 |
| 115 | 94 OBRA'A' 33 | 4 OBRA'A'420 | 0.00000 | 0.33833 | 0.00000 | 0.00000 | 1.00000 |
| 116 | 94 OBRA'A' 33 | 2 OBRA(TH)220 | 0.00000 | 0.28666 | 0.00000 | 0.00000 | 1.00000 |
| 117 | 95 OBRA'B' 33 | 92 OBRA'B'420 | 0.00000 | 0.33833 | 0.00000 | 0.00000 | 1.00000 |
| 118 | 95 OBRA'B' 33 | 2 OBRA(TH)220 | 0.00000 | 0.28666 | 0.00000 | 0.00000 | 1.00000 |
| 119 | 96 SLN 'A' 33 | 48 SLN'A' 400 | 0.00000 | 0.33833 | 0.00000 | 0.00000 | 1.00000 |
| 120 | 96 SLN 'A' 33 | 47 SLN 220 | 0.00000 | 0.28666 | 0.00000 | 0.00000 | 1.00000 |
| 121 | 97 SLN 'B' 33 | 93 SLN'B' 400 | 0.00000 | 0.33833 | 0.00000 | 0.00000 | 1.00000 |
| 122 | 97 SLN 'B' 33 | 47 SLN 220 | 0.00000 | 0.28666 | 0.00000 | 0.00000 | 1.00000 |
| 123 | 98 PANKI 33 | 9 PANKI 400 | 0.00000 | 0.16917 | 0.00000 | 0.00000 | 1.00000 |
| 124 | 98 PANKI 33 | 8 PANKI 220 | 0.00000 | 0.14333 | 0.00000 | 0.00000 | 1.00000 |
| 125 | 99 LKO 33 | 53 LUCKNOW400 | 0.00000 | 0.16917 | 0.00000 | 0.00000 | 1.00000 |
| 126 | 99 LKO 33 | 52 LUCKNOW220 | 0.00000 | 0.14333 | 0.00000 | 0.00000 | 1.00000 |
| 127 | 100 MURAD 33 | 64 MURAD 400 | 0.00000 | 0.16917 | 0.00000 | 0.00000 | 1.00000 |
| 128 | 100 MURAD 33 | 63 MURAD 220 | 0.00000 | 0.14333 | 0.00000 | 0.00000 | 1.00000 |

VOLTAGE CONTROLLED BUS DATA

| S.NO. | BUS NO. NAME | Q-MINIMUM | Q-MAXIMUM | SCHEDULED VOLTAGE |
|---|---|---|---|---|
| 1 | 3 OBRA A 15.75 | -15.0000 | 150.0000 | 1.0100 |
| 2 | 5 PANKI 11 | -3.2000 | 22.0000 | 1.0100 |
| 3 | 34 SAHUPURI 220 | -20.0000 | 20.0000 | 1.0300 |
| 4 | 12 HDJ'B' 11 | -16.5000 | 40.0000 | 0.9800 |
| 5 | 1 OBRA(TH)10.5 | -35.0000 | 90.0000 | 1.0000 |
| 6 | 18 KHATIMA 11 | -2.7600 | 15.0000 | 1.0500 |
| 7 | 20 CHILLA 11 | -7.2000 | 90.0000 | 1.0500 |
| 8 | 24 CHIBRO 11 | -12.0000 | 60.0000 | 1.0400 |
| 9 | 28 DHALIPUR 11 | -1.7000 | 20.0000 | 1.0400 |
| 10 | 73 RISH 220 | 0.0000 | 20.0000 | 1.0500 |
| 11 | 62 MURAD 132 | 0.0000 | 50.0000 | 1.0500 |
| 12 | 7 PANKI(EXT)11 | 0.0000 | 90.0000 | 1.0200 |
| 13 | 10 HDJ'A' 11 | 0.0000 | 10.0000 | 0.9800 |
| 14 | 14 RIHAND 11 | 0.0000 | 30.0000 | 0.9800 |
| 15 | 22 RAMGANGA 11 | 0.0000 | 30.0000 | 1.0200 |
| 16 | 26 DAKRANI 11 | 0.0000 | 20.0000 | 1.0500 |
| 17 | 30 KULHAL 11 | 0.0000 | 50.0000 | 1.0500 |
| 18 | 46 SLN 132 | -20.0000 | 30.0000 | 1.0200 |
| 19 | 85 MAINPURI220 | 0.0000 | 50.0000 | 1.0100 |

SHUNT LOAD DATA

| S.NO. | BUS NO. NAME | SHUNT LOAD AVAILABLE | |
|---|---|---|---|
| 1 | 31 ROBGANG 132 | 0.00000 | 0.05400 |
| 2 | 33 SAHUPURI132 | 0.00000 | 0.13800 |
| 3 | 36 MAU 132 | 0.00000 | 0.09500 |
| 4 | 37 GKP 132 | 0.00000 | 0.38600 |

| | | | | |
|---|---|---|---|---|
| 5 | 41 | FZD 132 | 0.00000 | 0.12100 |
| 6 | 46 | SLN 132 | 0.00000 | 0.05600 |
| 7 | 49 | ALLD 132 | 0.00000 | 0.08900 |
| 8 | 51 | LUCKNOW132 | 0.00000 | 0.07400 |
| 9 | 54 | SITAPUR182 | 0.00000 | 0.04400 |
| 10 | 56 | SHAJPUR132 | 0.00000 | 0.02400 |
| 11 | 58 | DHONA 132 | 0.00000 | 0.09900 |
| 12 | 6 | PANKI 132 | 0.00000 | 0.08300 |
| 13 | 11 | HDJ 132 | 0.00000 | 0.40300 |
| 14 | 59 | KHURJA 132 | 0.00000 | 0.22900 |
| 15 | 62 | MURAD 132 | 0.00000 | 0.20000 |
| 16 | 65 | MEERUT132 | 0.00000 | 0.10100 |
| 17 | 90 | SHAMLI132 | 0.00000 | 0.18700 |
| 18 | 70 | ROORKEE 52 | 0.00000 | 0.06900 |
| 19 | 78 | KASHPUR132 | 0.00000 | 0.03100 |
| 20 | 79 | MBD 132 | 0.00000 | 0.42600 |
| 21 | 85 | MAINPURI220 | 0.00000 | 0.07000 |
| 22 | 87 | MUZAFFR132 | 0.00000 | 0.35000 |
| 23 | 4 | OBRA'A'420 | 0.00000 | -1.00000 |
| 24 | 9 | PANKI 400 | 0.00000 | -1.00000 |
| 25 | 48 | SLN'A' 400 | 0.00000 | -0.50000 |
| 26 | 53 | LUCKNOW400 | 0.00000 | -0.50000 |
| 27 | 64 | MURAD 400 | 0.00000 | -0.50000 |
| 28 | 89 | AZAM132 | 0.00000 | 0.04500 |
| 29 | 92 | OBRA'B'420 | 0.00000 | 0.00000 |
| 30 | 40 | BASTI 62 | 0.00000 | 0.05000 |
| 31 | 68 | SAHAPUR132 | 0.00000 | 0.12000 |
| 32 | 94 | OBRA'A' 33 | 0.00000 | 0.00000 |
| 33 | 96 | SLN 'A' 33 | 0.00000 | 0.00000 |
| 34 | 77 | NEHTAUR132 | 0.00000 | 0.08800 |
| 35 | 98 | PANKI 33 | 0.00000 | 0.00000 |
| 36 | 99 | LKO 33 | 0.00000 | 0.00000 |
| 37 | 100 | MURAD 33 | 0.00000 | 0.00000 |

LIST OF OUTPUT RESULTS

DMAX = 0.00015998 EPSIL = 0.00100000

NEWTON RAPHSON ITERATIVE TECHNIQUE CONVERGED IN 7 ITERATIONS

| BUS | BUS NAME | VOLTAGE | ANGLE | GENERATION | | LOAD | |
|---|---|---|---|---|---|---|---|
| 1 | OBRA(TH)10.5 | 1.00000 | 0.00000 | 129.39452 | 103.62430 | 0.00000 | 0.00000 |
| 2 | OBRA(TH)220 | 1.03191 | -1.65877 | -0.00003 | 0.00028 | 58.20000 | 40.00000 |
| 3 | OBRA A 15.75 | 1.01000 | 5.95954 | 398.00000 | 137.66420 | 0.00000 | 0.00000 |
| 4 | OBRA'A'420 | 0.98579 | 1.35100 | 0.00001 | -0.00005 | 0.00000 | 0.00000 |
| 5 | PANKI 11 | 1.01000 | -0.34776 | 24.00000 | 17.25541 | 0.00000 | 0.00000 |
| 6 | PANKI 132 | 0.96523 | -4.22968 | 0.00000 | 0.00056 | 80.00000 | 60.00000 |
| 7 | PANKI(EXT)11 | 1.02000 | 3.83493 | 140.00000 | 52.56645 | 0.00000 | 0.00000 |
| 8 | PANKI 220 | 0.98502 | -2.54208 | 0.00003 | 0.00024 | 55.00000 | 34.50000 |
| 9 | PANKI 400 | 0.97271 | -1.37872 | 0.00000 | -0.00015 | 0.00000 | 0.00000 |
| 10 | HDJ'A' 11 | 0.95982 | -3.23760 | 22.00000 | 6.90086 | 0.00000 | 0.00000 |
| 11 | HDJ 132 | 1.00352 | -5.05613 | -0.00000 | 0.00107 | 110.00000 | 90.00000 |
| 12 | HDJ'B' 11 | 0.98000 | -2.00528 | 50.00000 | 39.36849 | 0.00000 | 0.00000 |
| 13 | HDJ 220 | 1.01467 | -3.43548 | -0.00002 | -0.00012 | 0.00000 | 0.00000 |
| 14 | RIHAND 11 | 0.97000 | -3.26373 | 40.00000 | 28.25042 | 0.00000 | 0.00000 |
| 15 | RIHAND 132 | 1.01442 | -4.01606 | -0.00004 | 0.00011 | 73.00000 | 58.00000 |
| 16 | OBRA(H) 11 | 0.96869 | -3.68541 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 17 | OBRA(H)132 | 1.02236 | -3.68541 | 0.00004 | 0.00023 | 18.00000 | 10.50000 |
| 18 | KHATIMA 11 | 1.05000 | 0.51914 | 25.00000 | 12.46170 | 0.00000 | 0.00000 |
| 19 | KHATIMA132 | 1.01844 | -3.30793 | 0.00000 | 0.00059 | 9.60000 | 8.00000 |
| 20 | CHILLA 11 | 1.05000 | 10.09414 | 131.00000 | 60.04496 | 0.00000 | 0.00000 |
| 21 | CHILLA 132 | 1.07562 | 5.98687 | -0.00003 | -0.00364 | 0.00000 | 0.00000 |
| 22 | RAMGANGA 11 | 1.02000 | 2.22662 | 48.00000 | 14.45755 | 0.00000 | 0.00000 |
| 23 | RAMGANGA132 | 1.06894 | 0.42576 | -0.00001 | 0.00053 | 2.50000 | 1.20000 |
| 24 | CHIBRO 11 | 1.04000 | 12.46404 | 120.00000 | -6.78747 | 0.00000 | 0.00000 |
| 25 | CHIBRO 220 | 1.05178 | 6.53243 | 0.00006 | -0.00213 | 0.00000 | 0.00000 |
| 26 | DAKRANI 11 | 1.05000 | 18.87955 | 33.00000 | 1.10543 | 0.00000 | 0.00000 |
| 27 | DAKRANI 132 | 1.05649 | 10.32559 | 0.00002 | -0.00532 | 2.50000 | 1.00000 |
| 28 | DHALIPUR 11 | 1.05985 | 18.35905 | 51.00000 | 3.74078 | 0.00000 | 0.00000 |
| 29 | DHALIPUR132 | 1.05914 | 10.52528 | -0.00007 | -0.00838 | 2.50000 | 1.00000 |
| 30 | KULHAL 11 | 1.05000 | 23.15570 | 79.99999 | 4.96951 | 0.00000 | 0.00000 |
| 31 | KULHAL 132 | 1.06072 | 10.71162 | -0.00010 | -0.01512 | 2.50000 | 1.00000 |
| 32 | ROBGANG 132 | 1.01560 | -4.55651 | -0.00003 | -0.00002 | 18.00000 | 13.50000 |
| 33 | SAHUPURI132 | 1.00781 | -6.23139 | 0.00001 | 0.00007 | 50.00000 | 42.00000 |
| 34 | SAHUPURI 220 | 1.02000 | -4.06952 | 0.00001 | 12.64091 | 0.00000 | 0.00000 |
| 35 | GAJIPUR 132 | 1.01663 | -7.41904 | 0.00000 | 0.00004 | 12.00000 | 7.20000 |
| 36 | MAU 132 | 1.03378 | -7.76921 | 0.00000 | -0.00003 | 13.20000 | 10.00000 |
| 37 | GKP 132 | 1.03327 | -8.83929 | 0.00001 | 0.00014 | 37.00000 | 35.00000 |
| 38 | GKP 220 | 1.03237 | -7.85072 | 0.00000 | 0.00001 | 0.00000 | 0.00000 |

39 0.00000

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 25 | CHIBRO 220 | 1.05178 | 6.53243 | 0.00006 | -0.00213 | 0.00000 | 0.00000 |
| 26 | DAKRANI 11 | 1.05000 | 18.87955 | 33.00000 | 1.10543 | 0.00000 | 0.00000 |
| 27 | DAKRANI 132 | 1.05649 | 10.32559 | 0.00002 | -0.00532 | 2.60000 | 1.00000 |
| 28 | DHALIPUR 11 | 1.05985 | 18.35905 | 51.00000 | 3.74078 | 0.00000 | 0.00000 |
| 29 | DHALIPUR132 | 1.05914 | 10.52528 | -0.00007 | -0.00838 | 2.50000 | 1.00000 |
| 30 | KULHAL 11 | 1.05000 | 23.15570 | 79.99999 | 4.96951 | 0.00000 | 0.00000 |
| 31 | KULHAL 132 | 1.06072 | 10.71162 | -0.00010 | -0.01512 | 2.50000 | 1.00000 |
| 32 | ROBGANG 132 | 1.01560 | -4.55651 | -0.00003 | -0.00002 | 18.00000 | 13.50000 |
| 33 | SAHUPURI132 | 1.00781 | -6.23139 | 0.00001 | 0.00007 | 50.00000 | 42.00000 |
| 34 | SAHUPURI 220 | 1.02000 | -4.06952 | 0.00001 | 12.64091 | 0.00000 | 0.00000 |
| 35 | GAJIPUR 132 | 1.01663 | -7.41904 | 0.00000 | 0.00004 | 12.00000 | 7.20000 |
| 36 | MAU 132 | 1.03378 | -7.76921 | 0.00000 | -0.00003 | 13.20000 | 10.00000 |
| 37 | GKP 132 | 1.03327 | -8.83929 | 0.00001 | 0.00014 | 32.00000 | 35.00000 |
| 38 | GKP 220 | 1.03237 | -7.85072 | 0.00000 | 0.00001 | 0.00000 | 0.00000 |
| 39 | KHALBAD 132 | 1.02283 | -9.66607 | 0.00001 | 0.00003 | 9.60000 | 6.00000 |
| 40 | BASTI 62 | 1.02031 | -10.00920 | 0.00001 | 0.00004 | 9.60000 | 6.00000 |
| 41 | FZD 132 | 1.00797 | -8.75196 | -0.00000 | 0.00007 | 16.00000 | 16.00000 |
| 42 | MANDADIH132 | 0.94747 | -8.56428 | 0.00001 | 0.00003 | 22.00000 | 20.00000 |
| 43 | JAUNPUR 152 | 0.91694 | -9.91312 | -0.00001 | 0.00002 | 15.00000 | 12.00000 |
| 44 | MIRZAPUR152 | 1.00507 | -5.54804 | 0.00001 | -0.00002 | 8.00000 | 5.00000 |
| 45 | JIGNA 132 | 1.00206 | -5.68727 | 0.00000 | 0.00003 | 8.00000 | 6.00000 |
| 46 | SLN 132 | 1.02000 | -7.58870 | -0.00001 | 28.37426 | 58.00000 | 50.58000 |
| 47 | SLN 220 | 1.02923 | -5.56508 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 48 | SLN'A' 400 | 0.96954 | -2.27964 | -0.00000 | -0.00043 | 0.00000 | 0.00000 |
| 49 | ALLD 132 | 1.04787 | -3.68467 | -0.00000 | 0.00013 | 34.00000 | 34.00000 |
| 50 | ALLD 220 | '.02014 | -2.15370 | 0.00000 | -0.00015 | 0.00000 | 0.00000 |
| 51 | LUCKNOW132 | 0.95373 | -4.76023 | -0.00000 | 0.00037 | 50.00000 | 31.00000 |
| 52 | LUCKNOW220 | 0.96407 | -3.13441 | -0.00001 | -0.00034 | 0.00000 | 0.00000 |
| 53 | LUCKNOW400 | 0.97653 | -2.63423 | 0.00000 | -0.00003 | 0.00000 | 0.00000 |
| 54 | SITAPUR182 | 0.95741 | -5.32063 | -0.00000 | 0.00035 | 28.00000 | 18.00000 |
| 55 | SITAPUR220 | 0.96193 | -4.11007 | 0.00001 | -0.00014 | 0.00000 | 0.00000 |
| 56 | SHAJPUR132 | 0.98232 | -5.08892 | -0.00000 | 0.00060 | 22.00000 | 13.50000 |
| 57 | SHAHPUR220 | 0.98232 | -5.08892 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 58 | DHONA 132 | 1.00632 | -3.95914 | -0.00001 | 0.00068 | 32.00000 | 31.00000 |
| 59 | KHURJA 132 | 1.02437 | -4.57611 | 0.00002 | 0.00018 | 20.00000 | 17.00000 |
| 60 | KHURJA 220 | 1.01213 | -3.09183 | 0.00002 | -0.00029 | 0.00000 | 0.00000 |
| 61 | BHOOR 132 | 1.02308 | -4.30306 | -0.00003 | -0.00002 | 0.00000 | 25.00000 |
| 62 | MURAD 132 | 1.05000 | -4.20543 | 0.00000 | 29.03238 | 60.00000 | 48.00000 |
| 63 | MURAD 220 | 1.00954 | -2.27503 | 0.00000 | -0.00270 | 0.00000 | 0.00000 |
| 64 | MURAD 400 | 0.97946 | -2.08277 | -0.00000 | 0.00009 | 0.00000 | 0.00000 |
| 65 | MEERUT132 | 0.99721 | -2.55182 | 0.00000 | -0.00017 | 40.00000 | 40.00000 |
| 66 | MEERUT220 | 1.01132 | -1.49732 | 0.00001 | -0.00087 | 0.00000 | 0.00000 |
| 67 | SHAMLI220 | 1.03252 | 1.08084 | -0.00000 | -0.00450 | 0.00000 | 0.00000 |
| 68 | SAHAPUR132 | 1.07885 | 3.61730 | -0.00001 | -0.00123 | 18.00000 | 18.00000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 69 | SAHAPUR220 | 1.04114 | 4.23738 | -0.00001 | -0.00591 | 0.00000 | 0.00000 |
| 70 | ROURKEE 52 | 1.07174 | 3.68174 | -0.00003 | -0.00236 | 6.00000 | 5.00000 |
| 71 | HARDWAR132 | 1.06832 | 5.27604 | -0.00001 | -0.00025 | 18.00000 | 16.00000 |
| 72 | RISH 132 | 1.05715 | 6.16039 | 0.00004 | -0.00775 | 22.00000 | 17.00000 |
| 73 | RISH 220 | 1.05000 | 4.09626 | 0.00000 | -17.74436 | 0.00000 | 0.00000 |
| 74 | DDN 132 | 1.05482 | 8.12917 | -0.00000 | -0.01355 | 13.00000 | 10.00000 |
| 75 | KHODRI 132 | 1.05304 | 9.94136 | -0.00001 | -0.00501 | 2.60000 | 1.00000 |
| 76 | KHODRI 220 | 1.05172 | 6.46886 | 0.00001 | -0.01600 | 0.00000 | 0.00000 |
| 77 | NEHTAUR132 | 1.05508 | 0.26898 | 0.00001 | -0.00434 | 20.00000 | 24.00000 |
| 78 | KASHPUR132 | 1.05818 | -0.48697 | 0.00003 | 0.00030 | 5.00000 | 3.00000 |
| 79 | MBD 132 | 1.04126 | -1.92796 | 0.00000 | 0.00017 | 36.00000 | 36.00000 |
| 80 | MBD 220 | 1.00456 | -2.40857 | -0.00000 | 0.00031 | 0.00000 | 0.00000 |
| 81 | GAJRALA 72 | 1.00337 | -3.10198 | 0.00001 | 0.00010 | 9.00000 | 7.00000 |
| 82 | HAPUR 132 | 0.97461 | -3.87003 | -0.00001 | 0.00031 | 18.00000 | 18.00000 |
| 83 | SHAGANJ132 | 0.91127 | -10.17230 | -0.00000 | 0.00002 | 5.00000 | 4.00000 |
| 84 | HALDWANI132 | 1.04824 | -0.92399 | -0.00000 | 0.00018 | 8.00000 | 6.00000 |
| 85 | MAINPURI220 | 1.01000 | -4.05051 | 0.00000 | 45.54347 | 55.00000 | 48.00000 |
| 86 | MUZAFFR220 | 1.03005 | 0.46595 | 0.00001 | -0.00149 | 0.00000 | 0.00000 |
| 87 | MUZAFFR132 | 1.03387 | -0.14671 | 0.00000 | -0.00049 | 32.00000 | 30.00000 |
| 88 | AZAM220 | 1.00598 | -5.53140 | 0.00001 | 0.00000 | 0.00000 | 0.00000 |
| 89 | AZAM132 | 0.98996 | -7.36138 | 0.00001 | 0.00002 | 10.00000 | 7.50000 |
| 90 | SHAMLI132 | 1.03725 | 0.43283 | -0.00001 | -0.00056 | 15.00000 | 12.00000 |
| 91 | OBRA'B'15.75 | 0.98862 | -1.65877 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 92 | OBRA'B'420 | 0.98862 | -1.65877 | 0.00000 | -0.00005 | 0.00000 | 0.00000 |
| 93 | SLN'B' 400 | 0.96729 | -5.56508 | 0.00000 | -0.00002 | 0.00000 | 0.00000 |
| 94 | OBRA'A' 33 | 1.01041 | -0.31244 | 0.00000 | 0.00002 | 0.00000 | 0.00000 |
| 95 | OBRA'B' 33 | 1.01206 | -1.65877 | 0.00000 | 0.00001 | 0.00000 | 0.00000 |
| 96 | SLN 'A' 33 | 1.00144 | -4.10683 | 0.00000 | -0.00001 | 0.00000 | 0.00000 |
| 97 | SLN 'B' 33 | 1.00082 | -5.56508 | 0.00000 | -0.00001 | 0.00000 | 0.00000 |
| 98 | PANKI 33 | 0.97932 | -2.01212 | 0.00000 | -0.00002 | 0.00000 | 0.00000 |
| 99 | LKO 33 | 0.96978 | -2.90340 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 100 | MURAD 33 | 0.99574 | -2.18829 | -0.00000 | 0.00002 | 0.00000 | 0.00000 |

TOTAL GENERATION = 1291.394500 573.353480 TOTAL LOAD = 1263.700000 1054.480000 TOTAL LOSSES = 27.694458 -481.126530

LIST OF OUTPUT RESULTS

DMAX = 0.00048400 EPSIL = 0.00100000

DECOUPLED ITERATIVE TECHNIQUE CONVERGED IN 9 ITERATIONS

7

| BUS | BUS NAME | VOLTAGE | ANGLE | GENERATION | | LOAD | |
|---|---|---|---|---|---|---|---|
| 1 | OBRA(TH)10.5 | 1.00000 | 0.00000 | 129.47353 | 103.57990 | 0.00000 | 0.00000 |
| 2 | OBRA(TH)220 | 1.03192 | -1.65977 | 0.00256 | 0.01113 | 58.20000 | 40.00000 |
| 3 | OBRA A 15.75 | 1.01000 | 5.95762 | 398.00002 | 137.56643 | 0.00000 | 0.00000 |
| 4 | OBRA'A'420 | 0.98581 | 1.34917 | 0.00014 | 0.00150 | 0.00000 | 0.00000 |
| 5 | PANKI 11 | 1.01000 | -0.35102 | 23.99999 | 17.23487 | 0.00000 | 0.00000 |
| 6 | PANKI 132 | 0.96529 | -4.23271 | 0.00004 | 0.00011 | 80.00000 | 60.00000 |
| 7 | PANKI(EXT)11 | 1.02000 | 3.83127 | 139.99996 | 52.48405 | 0.00000 | 0.00000 |
| 8 | PANKI 220 | 0.98508 | -2.54532 | -0.00004 | 0.00069 | 55.00000 | 34.50000 |
| 9 | PANKI 400 | 0.97280 | -1.38258 | -0.00007 | -0.00064 | 0.00000 | 0.00000 |
| 10 | HDJ'A' 11 | 0.96500 | -3.26352 | 21.99997 | 9.69376 | 0.00000 | 0.00000 |
| 11 | HDJ 132 | 1.00501 | -5.06962 | -0.00022 | -0.00028 | 110.00000 | 90.00000 |
| 12 | HDJ'B' 11 | 0.98000 | -2.02024 | 49.99994 | 3[illegible].18531 | 0.00000 | 0.00000 |
| 13 | HDJ 220 | 1.01527 | -3.44960 | 0.00003 | -0.00065 | 0.00000 | 0.00000 |
| 14 | RIHAND 11 | 0.97000 | -3.26482 | 39.99997 | 28.22650 | 0.00000 | 0.00000 |
| 15 | RIHAND 132 | 1.01443 | -4.01714 | -0.00229 | 0.04130 | 73.00000 | 58.00000 |
| 16 | OBRA(H) 11 | 0.96869 | -3.68634 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 17 | OBRA(H)132 | 1.02236 | -3.68634 | 0.00483 | -0.04472 | 18.00000 | 10.50000 |
| 18 | KHATIMA 11 | 1.05000 | 0.50441 | 25.00003 | 12.10095 | 0.00000 | 0.00000 |
| 19 | KHATIMA132 | 1.01937 | -3.31919 | 0.00483 | -0.00855 | 9.60000 | 8.00000 |
| 20 | CHILLA 11 | 1.05000 | 10.07736 | 131.00021 | 59.98355 | 0.00000 | 0.00000 |
| 21 | CHILLA 132 | 1.07566 | 5.97021 | 0.02153 | -0.02100 | 0.00000 | 0.00000 |
| 22 | RAMGANGA 11 | 1.02500 | 2.13775 | 47.99992 | 17.62359 | 0.00000 | 0.00000 |
| 23 | RAMGANGA132 | 1.07006 | 0.35090 | 0.01158 | -0.02347 | 2.50000 | 1.20000 |
| 24 | CHIBRO 11 | 1.04000 | 12.46405 | 119.99994 | -6.45591 | 0.00000 | 0.00000 |
| 25 | CHIBRO 220 | 1.05148 | 6.53075 | 0.00034 | -0.00020 | 0.00000 | 0.00000 |
| 26 | DAKRANI 11 | 1.05000 | 18.91734 | 32.99995 | 1.51915 | 0.00000 | 0.00000 |
| 27 | DAKRANI 132 | 1.05454 | 10.34747 | 0.00216 | -0.00367 | 2.50000 | 1.00000 |
| 28 | DHALIPUR 11 | 1.04500 | 18.51562 | 50.99990 | -0.63088 | 0.00000 | 0.00000 |
| 29 | DHALIPUR132 | 1.05700 | 10.55365 | -0.00319 | -0.00088 | 2.50000 | 1.00000 |
| 30 | KULHAL 11 | 1.05000 | 23.20564 | 79.99994 | 5.67775 | 0.00000 | 0.00000 |
| 31 | KULHAL 132 | 1.05875 | 10.73796 | 0.00787 | -0.02005 | 2.50000 | 1.00000 |
| 32 | ROBGANG 132 | 1.01561 | -4.55755 | -0.00129 | 0.01060 | 18.00000 | 13.50000 |
| 33 | SAHUPURI132 | 1.00781 | -6.23233 | -0.00710 | 0.00307 | 50.00000 | 42.00000 |
| 34 | SAHUPURI 220 | 1.02000 | -4.07043 | -0.00249 | 12.59835 | 0.00000 | 0.00000 |
| 35 | GAJIPUR 132 | 1.01664 | -7.41959 | 0.00027 | -0.00220 | 12.00000 | 7.20000 |
| 36 | MAU 132 | 1.03379 | -7.76952 | 0.04840 | -0.01423 | 13.20000 | 10.00000 |
| 37 | GKP 132 | 1.03327 | -8.84059 | -0.01051 | -0.01038 | 32.00000 | 35.00000 |
| 38 | GKP 220 | 1.03237 | -7.85210 | 0.00041 | -0.00406 | 0.00000 | 0.00000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 39 | KHALBAD 132 | 1.02282 | -9.66750 | -0.00263 | -0.00016 | 9.60000 | 6.00000 |
| 40 | BASTI 62 | 1.02031 | -10.01065 | -0.00062 | -0.00072 | 9.60000 | 6.00000 |
| 41 | FZD 132 | 1.00798 | -8.75360 | 0.00298 | 0.00333 | 16.00000 | 16.00000 |
| 42 | MANDADIH132 | 0.94746 | -8.56541 | -0.00725 | -0.00043 | 22.00000 | 20.00000 |
| 43 | JAUNPUR 152 | 0.91692 | -9.91389 | 0.00132 | -0.00546 | 15.00000 | 12.00000 |
| 44 | MIRZAPUR152 | 1.00507 | -5.54911 | 0.00113 | -0.00126 | 8.00000 | 5.00000 |
| 45 | JIGNA 132 | 1.00206 | -5.68839 | -0.00231 | -0.00001 | 8.00000 | 6.00000 |
| 46 | SLN 132 | 1.02000 | -7.59048 | -0.00304 | 28.33423 | 58.00000 | 50.58000 |
| 47 | SLN 220 | 1.02925 | -5.56689 | -0.00028 | 0.00307 | 0.00000 | 0.00000 |
| 48 | SLN"A" 400 | 0.96958 | -2.28173 | -0.00012 | -0.00186 | 0.00000 | 0.00000 |
| 49 | ALLD 132 | 1.04789 | -3.68617 | 0.00007 | 0.00003 | 34.00000 | 34.00000 |
| 50 | ALLD 220 | 1.02015 | -2.15526 | -0.00246 | -0.01596 | 0.00000 | 0.00000 |
| 51 | LUCKNOW132 | 0.95390 | -4.76169 | -0.00001 | 0.00019 | 50.00000 | 31.00000 |
| 52 | LUCKNOW220 | 0.96^19 | -3.13728 | 0.00002 | -0.00075 | 0.00000 | 0.00000 |
| 53 | LUCKNOW400 | 0.97659 | -2.63674 | 0.00000 | 0.00023 | 0.00000 | 0.00000 |
| 54 | SITAPUR182 | 0.95782 | -5.32308 | 0.00123 | -0.00170 | 28.00000 | 18.00000 |
| 55 | SITAPUR220 | 0.96218 | -4.11380 | 0.00005 | -0.00011 | 0.00000 | 0.00000 |
| 56 | SHAJPUR132 | 0.98333 | -5.10015 | 0.00065 | 0.00104 | 22.00000 | 13.50000 |
| 57 | SHAHPUR220 | 0.98333 | -5.10015 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 58 | DHONA 132 | 1.00755 | -3.97625 | -0.00620 | 0.00 78 | 32.00000 | 31.00000 |
| 59 | KHURJA 132 | 1.02515 | -4.58410 | -0.00101 | 0.00203 | 20.00000 | 17.00000 |
| 60 | KHURJA 220 | 1.01261 | -3.10336 | 0.00040 | 0.00029 | 0.00000 | 0.00000 |
| 61 | BHOOR 132 | 1.02366 | -4.31008 | 0.00201 | -0.00217 | 0.00000 | 25.00000 |
| 62 | MURAD 132 | 1.05000 | -4.20955 | -0.00055 | 28.12147 | 60.00000 | 48.00000 |
| 63 | MURAD 220 | 1.00979 | -2.28278 | 0.00051 | -0.00039 | 0.00000 | 0.00000 |
| 64 | MURAD 400 | 0.97967 | -2.08982 | 0.00001 | 0.00041 | 0.00000 | 0.00000 |
| 65 | MEERUT132 | 0.99741 | -2.55928 | 0.00000 | -0.00001 | 40.00000 | 40.00000 |
| 66 | MEERUT220 | 1.01152 | -1.50518 | -0.00003 | -0.00005 | 0.00000 | 0.00000 |
| 67 | SHAMLI220 | 1.03260 | 1.07258 | 0.00012 | -0.00054 | 0.00000 | 0.00000 |
| 68 | SAHAPUR132 | 1.07910 | 3.60479 | 0.00359 | -0.00474 | 18.00000 | 18.00000 |
| 69 | SAHAPUR220 | 1.04109 | 4.22940 | -0.00079 | 0.00002 | 0.00000 | 0.00000 |
| 70 | ROURKEE 52 | 1.07215 | 3.66214 | -0.00186 | 0.01344 | 5.00000 | 5.00000 |
| 71 | HARDWAR132 | 1.06840 | 5.25928 | -0.01104 | 0.01612 | 18.00000 | 16.00000 |
| 72 | RISH 132 | 1.05686 | 6.14898 | -0.00311 | -0.01062 | 22.00000 | 17.00000 |
| 73 | RISH 220 | 1.05000 | 4.08829 | 0.00037 | -17.15502 | 0.00000 | 0.00000 |
| 74 | DON 132 | 1.05368 | 8.13333 | -0.01036 | 0.02423 | 13.00000 | 10.00000 |
| 75 | KHODRI 132 | 1.05124 | 9.95706 | -0.00093 | 0.01333 | 2.50000 | 1.00000 |
| 76 | KHODRI 220 | 1.05142 | 6.46718 | 0.00002 | 0.00048 | 0.00000 | 0.00000 |
| 77 | NEHTAUR132 | 1.05680 | 0.22740 | -0.01662 | 0.02473 | 20.00000 | 24.00000 |
| 78 | KASHPUR132 | 1.05094 | -0.54850 | -0.00235 | 0.01061 | 5.00000 | 3.00000 |
| 79 | MBD 132 | 1.04295 | -1.95995 | 0.01112 | -0.01201 | 36.00000 | 36.00000 |
| 80 | MBD 220 | 1.00582 | -2.43662 | -0.00115 | 0.00070 | 0.00000 | 0.00000 |
| 81 | GAJRALA 72 | 1.00515 | -3.13075 | -0.00481 | 0.00211 | 9.00000 | 7.00000 |
| 82 | HAPUR 132 | 0.97641 | -3.89629 | -0.00123 | -0.00023 | 18.00000 | 18.00000 |
| 83 | SHAGAR.J132 | 0.91124 | -10.17300 | 0.00054 | -0.00183 | 5.00000 | 4.00000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | -0.00149 | 0.00076 | 4.00000 | 6.00000 |
| [illegible] | [illegible] | [illegible] | [illegible]55275 | 0.00067 | 44.21131 | 55.00000 | 43.00000 |
| [illegible] | [illegible] | 1.03[illegible] | [illegible] | 0.00012 | -0.00010 | 0.00000 | 0.00000 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | -0.00021 | 32.00000 | 10.00000 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 0.00000 |
| [illegible] | [illegible] | [illegible] | -7.36[illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | 0.42[illegible] | [illegible]27 | [illegible] | 15.00000 | 12.00000 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 0.00000 | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | 1.01[illegible] | [illegible] | [illegible] | [illegible]02 | [illegible] | [illegible] |
| [illegible] | [illegible] | 1.01207 | [illegible] | [illegible] | [illegible] | [illegible] | 0.00000 |
| [illegible] | [illegible] | 1.00147 | [illegible] | [illegible] | 0.00001 | [illegible] | 0.00000 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | -0.00001 | 0.00000 | [illegible] |
| [illegible] | [illegible] | 0.97940 | [illegible] | [illegible] | 0.00000 | [illegible] | 0.00000 |
| [illegible] | LEO 33 | 0.96987 | -2.9[illegible] | 0.00006 | 0.00000 | 0.00000 | 0.00000 |
| 100 | MURAD 33 | 0.99547 | -2.1[illegible] | - .00000 | -0.00001 | 0.00000 | 0.00000 |

TOTAL GENERATION = 1291.476209 572.937730 TOTAL LOAD = 1253.700000 1054.480000 TOTAL LOSSES = 27.776245 -481.542280

## LIST OF OUTPUT RESULTS

DMAX = 0.00028205 EPSIL = 0.00100000

FAST DECOUPLED ITERATIVE TECHNIQUE CONVERGED IN 7 ITERATIONS

| BUS | BUS NAME | VOLTAGE | ANGLE | GENERATION | | LOAD | |
|---|---|---|---|---|---|---|---|
| 1 | OBRA(TH)10.5 | 1.00000 | 0.00000 | 129.34065 | 87.37264 | 0.00000 | 0.00000 |
| 2 | OBRA(TH)220 | 1.03566 | -1.65207 | 0.00066 | -0.00512 | 0.00000 | 0.00000 |
| 3 | OBRA A 15.75 | 1.01000 | 5.95393 | 398.00004 | 129.94623 | 58.20000 | 40.00000 |
| 4 | OBRA'A'420 | 0.98732 | 1.35254 | 0.00001 | 129.94623 | 0.00000 | 0.00000 |
| 5 | PANKI 11 | 1.01000 | -0.31665 | 0.00001 | -0.00056 | 0.00000 | 0.00000 |
| 6 | PANKI 132 | 0.96613 | -4.19495 | 24.00000 | 16.92489 | 0.00000 | 0.00000 |
| 7 | PANKI(EXT)11 | 1.02000 | 3.85967 | 0.00001 | 0.00002 | 80.00000 | 60.00000 |
| 8 | PANKI 220 | 0.98604 | -2.51068 | 139.99999 | 51.24441 | 0.00000 | 0.00000 |
| 9 | PANKI 400 | 0.97384 | -1.35406 | 0.00008 | 0.00008 | 55.00000 | 34.50000 |
| 10 | HDJ'A' 11 | 0.98000 | -3.26549 | -0.00004 | 0.00028 | 0.00000 | 0.00000 |
| 11 | HDJ 132 | 1.00889 | -5.03709 | 22.00001 | 18.26205 | 0.00000 | 0.00000 |
| 12 | HDJ'B' 11 | 0.98000 | -1.98950 | -0.00012 | 0.00033 | 110.00000 | 90.00000 |
| 13 | HDJ 220 | 1.01644 | -3.41721 | 50.00003 | 35.88148 | 0.00000 | 0.00000 |
| 14 | RIHAND 11 | 0.98000 | -3.28414 | -0.00045 | 0.00046 | 0.00000 | 0.00000 |
| 15 | RIHAND 132 | 1.02265 | -4.02280 | 39.99999 | 35.58976 | 0.00000 | 0.00000 |
| 16 | OBRA(H) 11 | 0.97506 | -3.66167 | -0.00073 | 0.00148 | 73.00000 | 58.00000 |
| 17 | OBRA(H)132 | 1.02906 | -3.66167 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 18 | KHATIMA 11 | 1.05000 | 0.54799 | -0.00109 | 0.00232 | 18.00000 | 10.50000 |
| 19 | KHATIMA132 | 1.01986 | -3.27752 | 24.99999 | 12.28831 | 0.00000 | 0.00000 |
| 20 | CHILLA 11 | 1.05000 | 10.13141 | -0.00116 | 0.00282 | 9.60000 | 8.00000 |
| 21 | CHILLA 132 | 1.07515 | 6.02237 | 130.99904 | 60.84149 | 0.00000 | 0.00000 |
| 22 | RAMGANGA 11 | 1.02000 | 7.25367 | -0.01547 | 0.03032 | 0.00000 | 0.00000 |
| 23 | RAMGANGA132 | 1.06709 | 0.45307 | 47.99966 | 14.24049 | 0.00000 | 0.00000 |
| 24 | CHIBRO 11 | 1.04000 | 12.51854 | -0.01254 | 0.02501 | 2.50000 | 1.20000 |
| 25 | CHIBRO 220 | 1.03126 | 6.58398 | 120.00028 | -6.21194 | 0.00000 | 0.00000 |
| 6 | DAKRANI 11 | 1.05000 | 18.98558 | -0.00019 | 0.00001 | 0.00000 | 0.00000 |
| 7 | DAKRANI 132 | 1.05375 | 10.40876 | 33.00006 | 1.69887 | 0.00000 | 0.00000 |
| 8 | DHALIPUR 11 | 1.04000 | 18.62479 | -0.00158 | 0.00295 | 2.50000 | 1.00000 |
| 9 | DHALIPUR132 | 1.05608 | 10.61727 | 50.99996 | -7.00517 | 0.00000 | 0.00000 |
| 0 | KULHAL 11 | 1.05000 | 23.27892 | -0.00312 | 0.00623 | 2.50000 | 1.00000 |
| 1 | KULHAL 132 | 1.05738 | 10.80087 | 79.99978 | 5.98804 | 0.00000 | 0.00000 |
| 2 | RAMGANG 132 | 1.02329 | -4.54319 | -0.01157 | 0.02114 | 2.50000 | 1.00000 |
| 3 | SAHUPURI132 | 1.01724 | -6.23327 | 0.00198 | -0.00413 | 18.00000 | 13.50000 |
| 4 | SAHUPURI 220 | 1.03000 | -[illegible].10900 | -0.00077 | 0.00164 | 50.00000 | 42.00000 |
| 5 | GAJIPUR 132 | 1.02559 | -7.10527 | 0.00005 | 31.12472 | 0.00000 | 0.00000 |
| 6 | MAU 132 | 1.04222 | -7.74419 | 0.00019 | -0.00042 | 12.00000 | 7.20000 |
| 7 | GKP 132 | 1.03410 | -8.77029 | 0.00236 | -0.00437 | 13.20000 | 10.00000 |
| 8 | GKP 220 | 1.03686 | -7.80275 | -0.00075 | 0.00161 | 32.00000 | 35.00000 |
| | | | | -0.00001 | -0.00001 | 0.00000 | 0.00000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 39 | KHALBAD 132 | 1.02879 | -9.58924 | 0.00031 | -0.00062 | 9.60000 | 6.00000 |
| 40 | BASTI 62 | 1.02634 | -9.92934 | 0.00013 | -0.00031 | 9.60000 | 6.00000 |
| 41 | FZD 132 | 1.00797 | -8.70082 | 0.00019 | -0.00046 | 15.00000 | 16.00000 |
| 42 | MANDADIH132 | 0.95787 | -8.52535 | 0.00006 | -0.00021 | 22.00000 | 20.00000 |
| 43 | JAUNPUR 152 | 0.92780 | -9.84616 | -0.00003 | 0.00008 | 15.00000 | 12.00000 |
| 44 | MIRZAPUR152 | 1.01300 | -5.52305 | 0.00010 | -0.00021 | 8.00000 | 5.00000 |
| 45 | JIGN, 132 | 1.01002 | -5.66037 | 0.00008 | -0.00025 | 8.00000 | 6.00000 |
| 46 | SLN 132 | 1.02000 | -7.53758 | -0.00020 | 25.44135 | 58.00000 | 50.58000 |
| 47 | SLN 220 | 1.03067 | -5.51678 | 0.00004 | 0.00015 | 0.00000 | 0.00000 |
| 48 | SLN'A' 400 | 0.97092 | -2.25303 | -0.00005 | 0.00013 | 0.00000 | 0.00000 |
| 49 | ALLD 132 | 1.05134 | -3.65602 | 0.00005 | -0.00010 | 34.00000 | 34.00000 |
| 50 | ALLD 220 | 1.02332 | -2.13485 | -0.00205 | 0.00449 | 0.00000 | 0.00000 |
| 51 | LUCKNOW132 | 0.95483 | -4.72660 | -0.00007 | -0.00009 | 50.00000 | 31.00000 |
| 52 | LUCKNOW220 | 0.96517 | -3.10361 | -0.00002 | -0.00016 | 0.00000 | 0.00000 |
| 53 | LUCKNOW400 | 0.97781 | -2.60556 | 0.00007 | 0.00014 | 0.00000 | 0.00000 |
| 54 | SITAPUR132 | 0.95841 | -5.28787 | -0.00008 | -0.00013 | 28.00000 | 18.00000 |
| 55 | SITAPUR220 | 0.96299 | -4.07812 | 0.00004 | 0.00021 | 0.00000 | 0.00000 |
| 56 | SHAJPUR132 | 0.98302 | -5.05891 | -0.00007 | 0.00006 | 22.00000 | 13.50000 |
| 57 | SHAHPUR220 | 0.98302 | -5.05891 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 58 | DHONA 132 | 1.00687 | -3.93111 | 0.00031 | -0.00107 | 32.00000 | 31.00000 |
| 59 | KHURJA 132 | 1.02709 | -4.53774 | 0.00042 | -0.00089 | 20.00000 | 17.00000 |
| 60 | KHURJA 220 | 1.01364 | -3.06696 | 0.00001 | -0.00015 | 0.00000 | 0.00000 |
| 61 | BHOOR 132 | 1.02509 | -4.26247 | -0.00046 | 0.00098 | 0.00000 | 25.00000 |
| 62 | MURAD 132 | 1.05000 | -4.15709 | 0.00001 | 25.88926 | 60.00000 | 48.00000 |
| 63 | MURAD 220 | 1.01040 | -2.24012 | -0.00023 | -0.00058 | 0.00000 | 0.00000 |
| 64 | MURAD 400 | 0.98037 | -2.04981 | 0.00008 | 0.00034 | 0.00000 | 0.00000 |
| 65 | MEERUT132 | 0.99789 | -2.51399 | -0.00004 | 0.00011 | 40.00000 | 40.00000 |
| 66 | MEERUT220 | 1.01198 | -1.46089 | 0.00005 | -0.00017 | 0.00000 | 0.00000 |
| 67 | SHAMLI220 | 1.03275 | 1.11942 | -0.00019 | -0.00017 | 0.00000 | 0.00000 |
| 68 | SAHAPUR132 | 1.07858 | 3.65582 | -0.00148 | 0.00104 | 18.00000 | 18.00000 |
| 69 | SAHAPUR220 | 1.04088 | 4.28103 | 0.00075 | -0.00084 | 0.00000 | 0.00000 |
| 70 | ROORKEE 52 | 1.07145 | 3.71722 | 0.00435 | -0.00774 | 6.00000 | 5.00000 |
| 71 | HARDWAR132 | 1.06783 | 5.31234 | 0.00416 | -0.00713 | 18.00000 | 16.00000 |
| 72 | RISH 132 | 1.05635 | 6.20064 | 0.00653 | -0.01423 | 22.00000 | 17.00000 |
| 73 | RISH 220 | 1.05000 | 4.13785 | -0.00094 | -16.67737 | 0.00000 | 0.00000 |
| 74 | DDN 132 | 1.05298 | 8.19017 | 0.00463 | -0.00854 | 13.00000 | 10.00000 |
| 75 | KHODRI 132 | 1.05046 | 10.31619 | 0.01128 | -0.02362 | 2.50000 | 1.00000 |
| 76 | KHODRI 220 | 1.05120 | 6.52041 | 0.00049 | -0.00145 | 0.00000 | 0.00000 |
| 77 | NEHTAUR132 | 1.05525 | 0.29574 | 0.00974 | -0.01758 | 20.00000 | 24.00000 |
| 78 | KASHPUR132 | 1.05842 | -0.46089 | 0.00645 | -0.01145 | 5.00000 | 3.00000 |
| 79 | MBD 132 | 1.04175 | -1.90515 | 0.00037 | -0.00391 | 36.00000 | 36.00000 |
| 80 | MBD 220 | 1.00548 | -2.38455 | 0.00048 | -0.00022 | 0.00000 | 0.00000 |
| 81 | GAJRALA 72 | 1.00389 | -3.07818 | -0.00087 | 0.00137 | 9.00000 | 7.00000 |
| 82 | HAPUR 132 | 0.97514 | -3.84548 | -0.00048 | 0.00120 | 18.00000 | 18.00000 |
| 83 | SHAGANJ132 | 0.92222 | -10.09983 | -0.00000 | 0.00002 | 5.00000 | 4.00000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 84 | HALDWANI132 | 1.04449 | -0.89771 | 0.00004 | -0.00018 | 8.00000 | 6.00000 |
| 85 | MAINPURI220 | 1.01000 | -4.00793 | -0.00012 | 40.32485 | 55.00000 | 48.00000 |
| 86 | MUZAFFR220 | 1.03042 | 0.50497 | 0.00026 | -0.00044 | 0.00000 | 0.00000 |
| 87 | MUZAFFR132 | 1.03422 | -0.10848 | -0.00037 | 0.00053 | 32.00000 | 30.00000 |
| 88 | AZAM220 | 1.01530 | -5.54313 | -0.00030 | 0.00069 | 0.00000 | 0.00000 |
| 89 | AZAM132 | 0.99840 | -7.35082 | -0.00228 | 0.00374 | 10.00000 | 7.50000 |
| 90 | SHAMLI132 | 1.03752 | 0.47194 | 0.00026 | -0.00032 | 15.00000 | 12.00000 |
| 91 | OBRA'B'15.75 | 0.99222 | -1.65207 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 92 | OBRA'B'420 | 0.99222 | -1.65207 | 0.00000 | -0.00004 | 0.00000 | 0.00000 |
| 93 | SLN'B' 400 | 0.96864 | -5.51678 | 0.00000 | -0.00004 | 0.00000 | 0.00000 |
| 94 | OBRA'A' 33 | 1.01315 | -0.30959 | -0.00001 | -0.00001 | 0.00000 | 0.00000 |
| 95 | OBRA'B' 33 | 1.01573 | -1.65207 | 0.00000 | 0.00001 | 0.00000 | 0.00000 |
| 96 | SLN 'A' 33 | 1.00286 | -4.06813 | 0.00000 | 0.00001 | 0.00000 | 0.00000 |
| 97 | SLN 'B' 33 | 1.00222 | -5.51678 | 0.00000 | -0.00001 | 0.00000 | 0.00000 |
| 98 | PANKI 33 | 0.98040 | -1.98375 | -0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 99 | LKO 33 | 0.97096 | -2.87356 | -0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 100 | MURAD 33 | 0.99663 | -2.15425 | 0.00001 | 0.00000 | 0.00000 | 0.00000 |

TOTAL GENERATION = 1291.336500 568.158410 TOTAL LOAD = 1263.700000 1054.480000 TOTAL LOSSES = 27.636551 -486.321600